The Proceedings of the Geophysical Society of Tulsa

Tenth Anniversary Number

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VOLUME 4 1956-57

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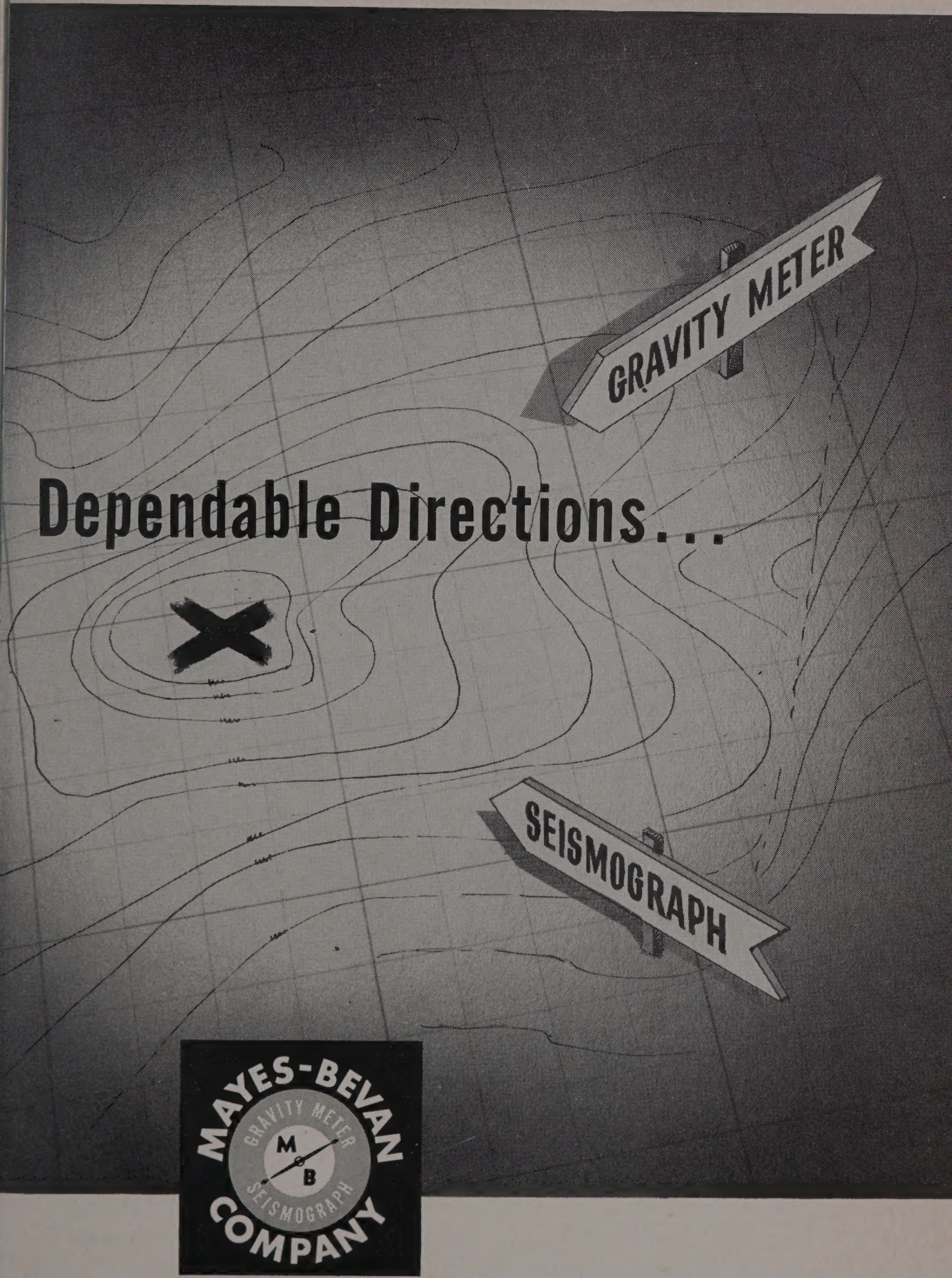
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To our local and out-of-town advertisers, we say thank you. Your past and present displays in the PROCEEDINGS are greatly appreciated. Were it not for your loyal support the financial status of this issue would be in grave jeopardy.

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The Editor.

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PROCEEDINGS OF THE GEOPHYSICAL SOCIETY OF TULSA

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VOLUME 4

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1956-1957

V. L. JONES, *Editor*

W. H. AUDLEY, *Assistant to the Editor*

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COMMITTEE TO DRAFT CONSTITUTION AND BY-LAWS FOR THE GEOPHYSICAL SOCIETY OF TULSA 1947. Left to Right seated: Colin C. Campbell, Jack Handley; Standing, Stanley W. Wilcox, V. L. Jones and Clare R. Coffin.

EDITOR'S FOREWORD

This issue of the PROCEEDINGS marks the tenth anniversary of the Geophysical Society of Tulsa. It was on February 4, 1947, that the formal organization of the society took place. The group photograph on the opposite page is that of the committee appointed by R. Clare Coffin, then temporary President, to draft the Constitution and By-Laws of what was to become the first local section of SEG.

Much water has gone over the dam since March 13, 1947, on which date Dr. M. B. Widess (Editor-Elect for 1957 - 1958), presented his paper, "Multiple Reflections in Seismic Surveying", at our first technical session. Since that time some twenty five local and student groups have petitioned and become affiliated with SEG. Ours, the first local section, has long since passed its growing pains, and has become one of the mature technical societies, of which there are many here in Tulsa.

The first issue of THE PROCEEDINGS OF THE GEOPHYSICAL SOCIETY OF TULSA, the Joseph A. Sharpe Memorial Volume, was published in 1953, with Dr. Robert J. Watson as Editor. Dr. Charles W. Oliphant edited Volume Two, which appeared in 1954. This was followed by Volume Three with E. V. McCollum as Editor in 1955. Like his predecessors, the present editor has endeavored to place in this issue original papers which are short, and in some cases controversial, but of special and general interest to the membership at large. This has been an enjoyable but oft-times nerve racking task.

Much of the credit for handling of printing matters and other details incident to the publication of this TENTH ANNIVERSARY NUMBER should go to W. H. Audley and Gene C. Conley, Assistant to the Editor and Business Manager respectively. Moreover, were it not for the indefatigable spirit, genial cooperation and many helpful suggestions of these two, this issue might well stilll be in its planning stages.

Credit and thanks are also extended to the Geophysical Department of Sunray Mid-Continent, which supplied much needed mimeograph and stenographic services.

Finally, the editor wishes to thank the authors as a group and as individuals for the splendid cooperation shown him in giving of their valuable time in the preparation of the manuscripts of their respective original papers which will be found herein.

V. L. JONES

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THE LOCUS OF POINTS HAVING EQUAL ARRIVAL-TIMES FOR A REFLECTED WAVE

by

WILLIAM SCHRIEVER†

The travel time for an explosion wave that has been reflected from a plane interface is given by the equation:

$$D^2 + (4\,N \sin\alpha)\,D \cos\varphi = t^2V^2 - 4\,N^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where D is the distance from the shot-point to the point at which the arrival time is t, N is the normal distance from the shot-point to the reflecting plane, α is the angle of dip of the reflecting plane, φ is the asmuth angle of the spread from the direction of the dip, and V is the constant phase velocity of the reflected wave in the medium above the reflecting plane.

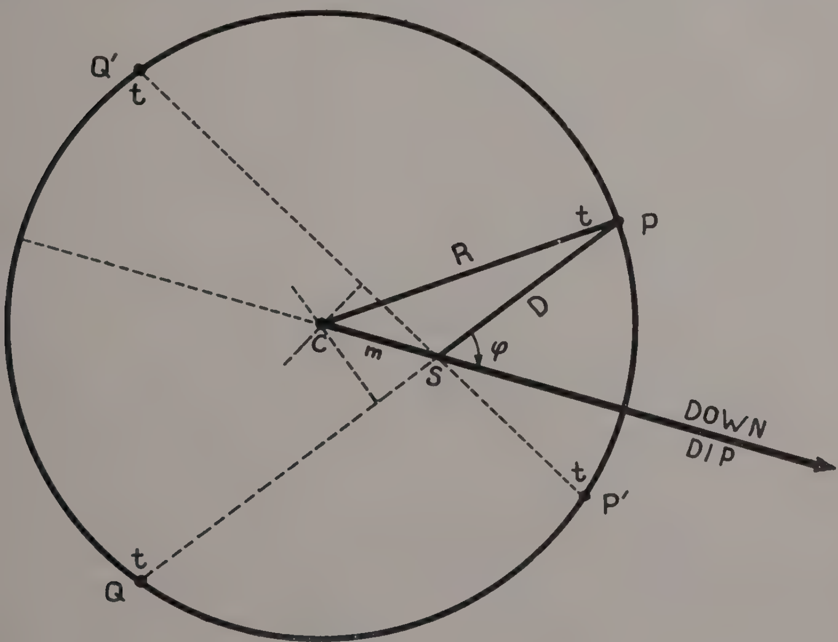


FIGURE 1. The locus of the points at which the reflected wave arrives simultaneously is a circle.

In Figure 1 the shot-point is at S, and P is a point on the level surface at which the reflected wave arrives in time t. By the law of cosines:

$$D^2 + (2m)\,D \cos\varphi = R^2 - m^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

†University of Oklahoma.

If R and m are constants equation (2) is the equation of a circle in the polar coordinates D and φ.

In equation (1), N, sin α, and V are constants. For the locus of points having the same arrival time, t will be constant. Therefore, equation (1) is also the equation of a circle in the polar coordinates D and φ.

A Graphical Solution

The two straight line spreads across the shot-point S have the direction PQ and P′Q′, and the points P, Q, P′ and Q′ are chosen such that the reflected wave arrives at these points at the same time, t. If the locations of these four points and the shot-points are drawn to scale as indicated in the figure, the perpendicular bisectors of PQ and P′ Q′ will meet in point C, the center of the circle which is the locus of all points having the same arrival time.

The direction of the dip is along the line from C to S, and the distance from C to S is m. The line CP is the radius R of the circular locus.

From equations (1) and (2) it is clear that:

$$4 \text{ N} \sin \alpha = 2 \text{ m} \qquad (3)$$

and:

$$t^2V^2 - 4 \text{ N}^2 = \text{R}^2 - \text{m}^2 \qquad (4)$$

Equation (4) may be solved for N:

$$\text{N} = (t^2V^2 + \text{m}^2 - \text{R}^2)^{1/2} / 2 \qquad (5)$$

whence sin α becomes:

$$\sin \alpha = \text{m} / (t^2V^2 + \text{m}^2 - \text{R}^2)^{1/2} \qquad (6)$$

From the graphical solution depicted by Figure 1, we may determine the values of R, m and φ. The time t is the chosen travel-time. The phase velocity V may be determined from a suitable velocity profile or in some other manner. Then the values of N and α may be calculated by use of equations (5) and (6).

Thus from the records of a pair of crossed spreads and the appropriate phase velocity for the reflected wave, we may obtain the direction of the dip, the magnitude of the dip, and the normal depth to the reflecting plane from the shot-point.

A TIME-DIP NOMOGRAM

by

PAUL L. LYONS†

Nomograms may be constructed to derive dips from seismic maps contoured in time. The chart here presented solves the dip when the rate of "time-dip" per mile is known, and when a particular velocity to the formation mapped is known. In this nomogram, straight line ray paths are assumed. Obviously, similar charts can be constructed when curvilinear paths for various velocity distributions are assumed.

Construction of Nomogram

From Figure 1, let the reflection time difference per mile, t_m, be divided by two and multiplied by a velocity V. Under the above assumption, the angle at A is a right angle, so that the sine of the angle of dip Θ is equal to $\frac{t_m V}{2 \times 5280}$ when the velocity is expressed in feet per second.

To make the nomogram, the relationship arc sin $\Theta = \frac{t_m V}{10560}$ is plotted with the "time-dip" per mile as the abscissa and V as the ordinate, and the curved lines are drawn with the arc or angle held constant.

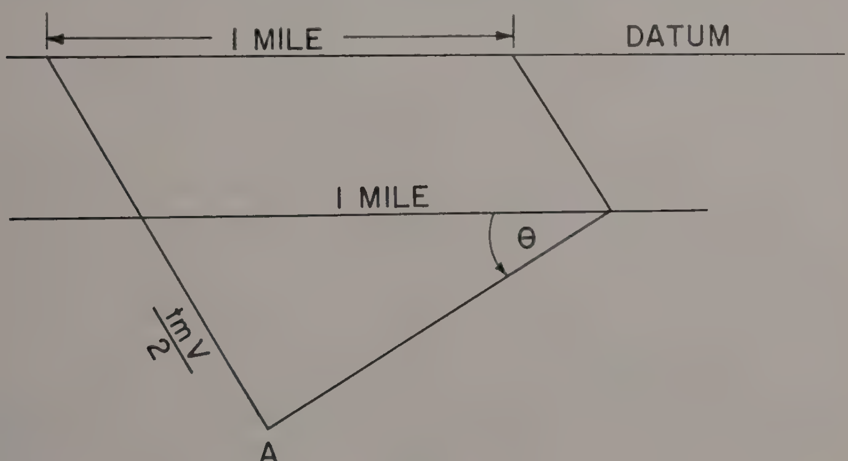


Figure 1.

Example

Suppose a contour map has the reflection times to a given reflection plotted at the stations for which the reflection times are observed. The dip is then normal to the contours, and the amount of "time-dip" in a scaled

†Sinclair Oil and Gas Company, Tulsa, Oklahoma

mile is observed along the normal, with the station for which the dip is desired located in the approximate center of the measured mile.

For example, suppose the time dip per mile is one tenth second and the velocity used for the distance involved is 10,000 feet per second. Then, by formula, the arc sin of the dip angle is $\frac{.1 \times 10{,}000}{10560}$ or 1000/10560. This equals .09469 which is the sine of 5° 26′. Of course, this is the value derived by interpolation of the nomogram.

Another use lies in the derivation of dips from plotted sections. If the times are plotted directly beneath the stations, a procedure identical with the above may be followed. In the event that the horizontal scale chosen is such as to make the horizontal and vertical scales of the section approximately equal in distance equivalents, then the dips may be measured directly from the section so plotted and the following theorem may be utilized.

The tangent of the plotted dip angle equals the sine of the true dip angle.

Hence the tangent of the measured angle may be compared to the nomogram angle with a sine equivalent to this tangent.

The conventional "migrations" or displacements of the station location to the subsurface origin of the ($X = O$) time path may be made by utilization of the obvious formulas provided with the chart. For this purpose, the sines and cosines to four places are noted along with the dip angles. The user may use his own judgment as to the errors involved in interpolating the chart values of these functions.

Other Uses

A variety of auxiliary uses of the chart are apparent.

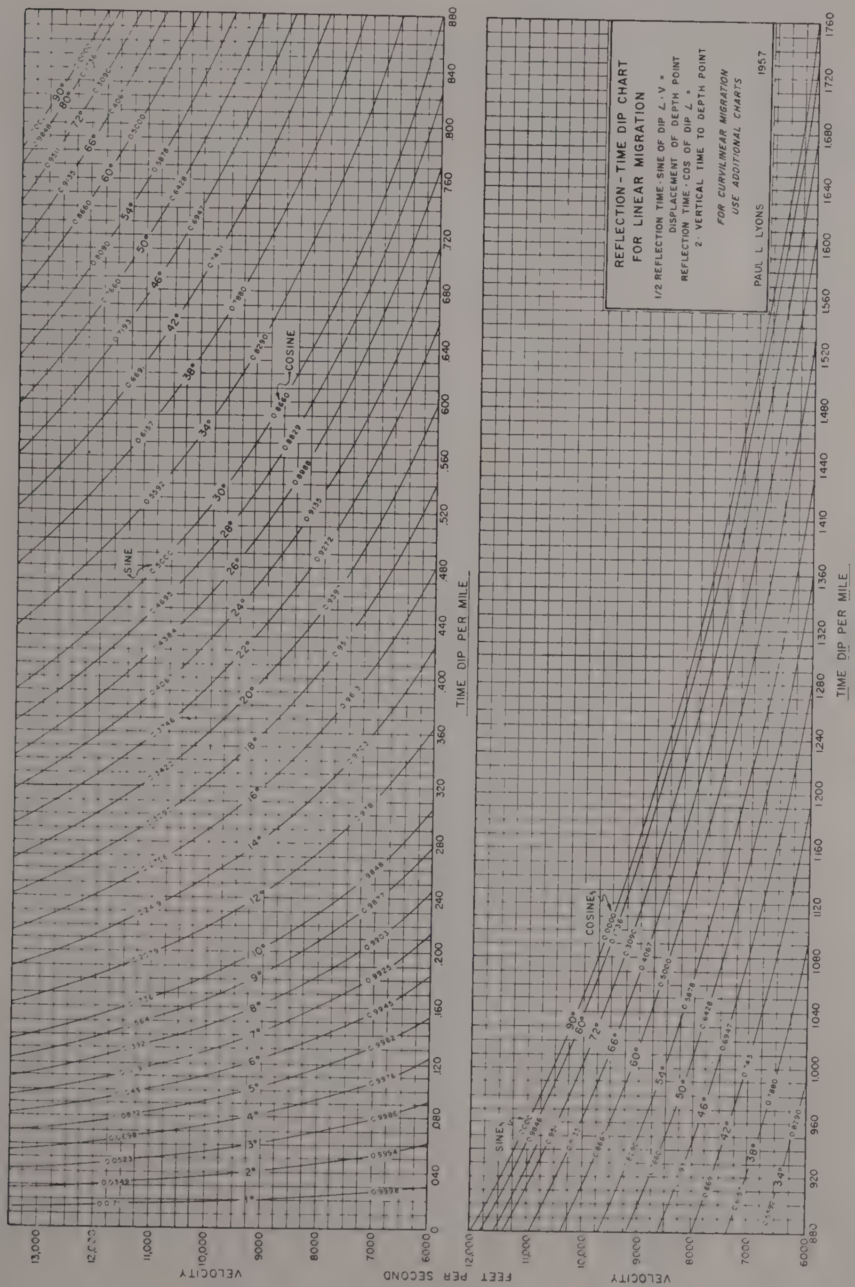
1. Suppose two wells are tied by seismic data and a uniform dip is known to exist between them. Then the known dip and the time-dip may be compared, using the chart, to obtain the velocity over the differential path involved.

2. Any rate of time-dip over a limited area may, of course, be extrapolated to "time-dip per mile".

3. If two profiles in line are available at a shot point, then the time difference, corrected for low velocity layer and elevations, between end points provides a "time dip" component for the distance between the corresponding depth points, provided the same "x" distances are chosen for each measured time value. The "time-dip" found will be for the distance "x", and this may in turn be converted to time-dip per mile. This is not strictly true, but is a very close approximation, especially if the dip angle involved is small.*

4. It is similarly possible to use the chart to determine true dip and strike (under the assumptions of the nomogram) when three or four

*Editor's Note—See paragraph following equation 7, in next succeeding paper.


REFLECTION - TIME DIP CHART
FOR LINEAR MIGRATION
1/2 REFLECTION TIME · SINE OF DIP ∠ · V = DISPLACEMENT OF DEPTH POINT
REFLECTION TIME · COS OF DIP ∠ = 2 · VERTICAL TIME TO DEPTH POINT
FOR CURVILINEAR MIGRATION USE ADDITIONAL CHARTS
PAUL L LYONS
1957
TIME DIP PER MILE
VELOCITY
FEET PER SECOND
SINE
COSINE

profiles are shot to determine dip. To do this, half the "x" distances for the corrected times chosen are plotted to scale around the shot point for which the determination is to be made. The corrected reflection times are noted at these points and *contoured*. This of course determines the strike and the "time-dip", so that the nomogram may be used to provide the dip and the migrated position of the shot point. As in (3), this is again a close approximation, with virtually no computational error for small angles. For large angles, it is apparent that errors of several degrees are not critical because of other considerations.

Conclusion

The interpreter who has need of a nomogram such as this is urged to experiment with larger charts and curvilinear paths. There is reason to suppose that similar simple nomograms can be used to provide the most rapid answers possible for a wide variety of dip calculations, using the rate principle of "time-dip".

VECTOR COMPOSITION OF REFLECTION TIME-GRADIENTS

by
WILLIAM SCHRIEVER†

Jakosky* states: "Hence, if the maximum gradient of the reflection time at a point S on the ground surface is $(dT/dx)_{max}$, and is directed, for

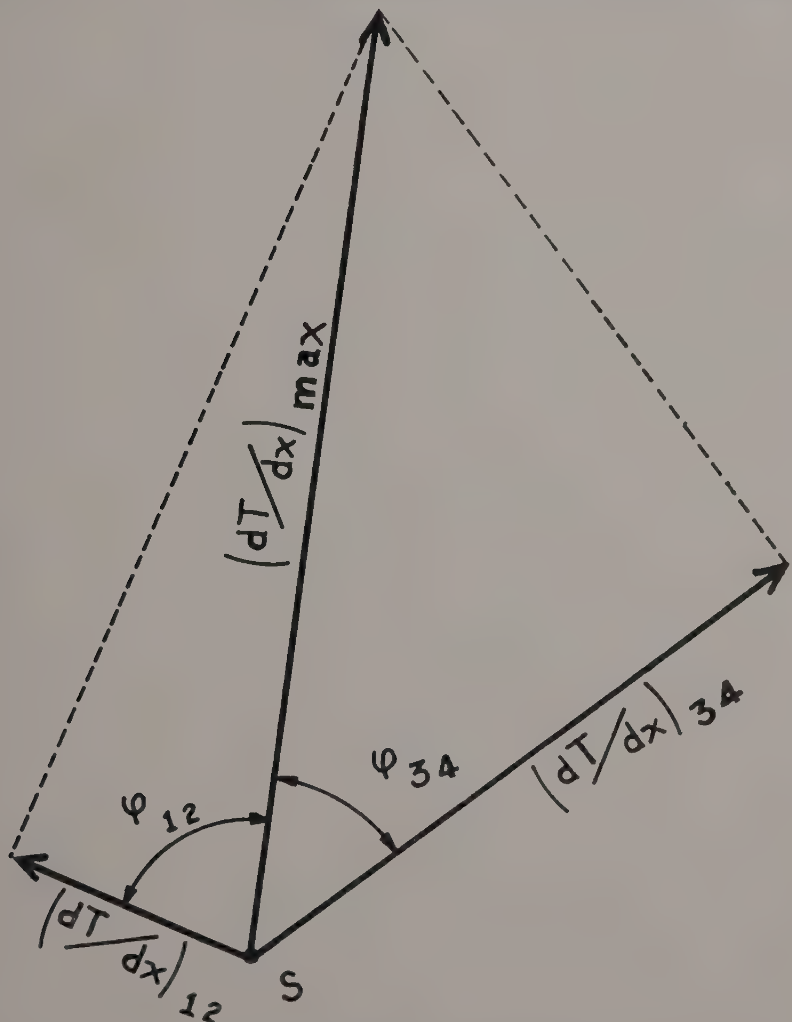


FIGURE 1. Jakosky's time — gradient diagram.

*J. J. Jakosky, Exploration Geophysics, 2nd ed., p. 712, Trija Publishing Co., Los Angeles, 1950.
†University of Oklahoma.

example, due north, the magnitude of the gradient at a bearing Φ is $(dT/dx)_{max}$ $\cos \Phi$." He states that the direction of the maximum time gradient will be exactly down dip, and he shows by a diagram, like Figure 1, how to obtain $(dT/dx)_{max}$ from the two observed time-gradiends, $(dT/dx)_{12}$ and $(dT/dx)_{34}$. He implies that this method of determining $(dT/dx)_{max}$ and the direction of maximum dip, is true for all magnitudes of the dip; at least he states no limitations. He does not give a derivation of his equation,

$$dT/dx = (dT/dx)_{max} \cos \Phi \qquad (1)$$

His definition of time gradient may be obtained from Figure 2. It is:

$$dT/dx = (t_d - t_u)/D \qquad (2)$$

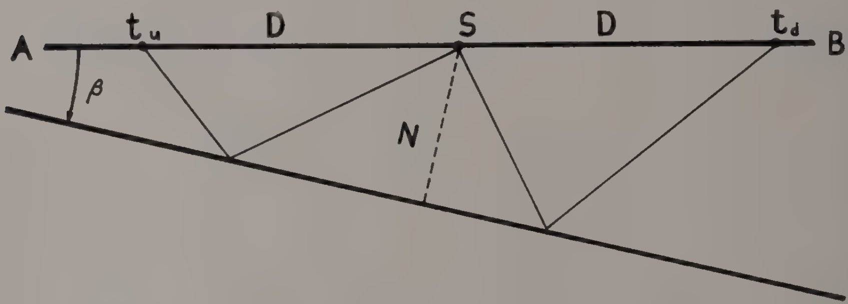


FIGURE 2. Reflected ray paths for equal distances from the shot-point.

where t_d and t_u are the travel times for the reflected wave and D is the distance from the shot-point to point of reception.

It is of interest to derive equation (1) in order to find the condition for which it is correct or approximately correct.

Derivation

The well-known equation for the travel time for a reflected wave is

$$t^2V^2 = 4\,N^2 + 4\,ND \sin \beta + D^2 \qquad (3)$$

where V is the constant phase velocity in the medium above the reflecting plane and N is the normal distance from the shot-point P to the reflecting plane. From this it follows that:

$$(t^2_d - t^2_u)\,V^2 = 8\,N\,D \sin \beta \qquad (4)$$

If the direction of AB of Figure 2 makes an angle φ with the direction of true dip, and if α is the angle of true dip, it can be shown that:

$$\sin \beta = \sin \alpha \cos \varphi \qquad (5)$$

If t_1 and t_2 are the respective values of t_d and t_u in the φ_{12} direction, and t_3 and t_4 are these values in the φ_{34} direction for the same D, and if (5) is substituted in (4), we have from the resulting equations:

$$\frac{\cos\varphi_{12}}{\cos\varphi_{34}} = \frac{t_1^2 - t_2^2}{t_3^2 - t_4^2} = \frac{t_1 - t_2}{t_3 - t_4} \cdot \frac{t_1 + t_2}{t_3 + t_4} \quad \ldots\ldots \quad (6)$$

This equation does not involve approximations.

From Jakosky's equations, equations (1) and (2), it follows, for equal values of D, that:

$$\frac{\cos\varphi_{12}}{\cos\varphi_{34}} = \frac{t_1 - t_2}{t_3 - t_4} \quad \ldots\ldots\ldots\ldots \quad (7)$$

From equation (6) it can be seen that Jakosky's relation, equation (7), will be approximately correct if $(t_1 + t_2) \cong (t_3 + t_4)$ for equal values of D. This will be the case for all orientations, approximately when the angle of dip is small. Equation (7) will hold exactly if it happens that $\varphi_{12} = \varphi_{34}$, since in this case $(t_1 + t_2) = (t_3 + t_4)$ exactly. Therefore, if φ_{12} is approximately equal to φ_{34}, equation (7) will give good results even for relatively large dips.

An Exact Calculation of φ

From the data for two equal spreads at right angles to each other it is easy to find the direction of true dip directly from the exact equation (6). For this case $\cos\varphi_{12}/\cos\varphi_{34}$ would be $\sin\varphi_{34}/\cos\varphi_{34} = \tan\varphi_{34}$. Therefore, for two spreads at right angles, we have:

$$\tan\varphi_{34} = \cot\varphi_{12} = \frac{t_1 - t_2}{t_3 - t_4} \cdot \frac{t_1 + t_2}{t_3 + t_4} \quad \ldots\ldots\ldots \quad (8)$$

AN INTEGRATED SYSTEM FOR MAGNETIC RECORDING AND PROCESSING SEISMIC DATA

by

P. C. SUNDT†

ABSTRACT

A magnetic recording system for seismic data has been developed which, rather than as an auxiliary for conventional recording equipment, has been designed as a complete system for performing all necessary operations from the seismic shot to the production of finished record cross sections. The use of pulse width modulation, besides allowing very close track spacing on the magnetic tape, has exhibited extremely good signal to noise characteristics and the facility for repeated transcription without deterioration of the signal, which is an essential quality when time correcting, compositing and re-recording of seismic traces.

The FR-1/MT-4 Magnetic Recording System described here was developed by the Carter Oil Company with the idea of utilizing the relatively new technique of magnetic recording to its fullest advantage in seismic prospecting.

Generally speaking, the system is composed of a field recorder which is used to record up to 24 channels of seismic information on magnetic tape with as much fidelity as possible, and an office playback machine which is used to process the field tapes, introducing time corrections, mixing between traces and presenting the final results on a record cross section.

The Field Recorder — The field recorder consists essentially of 24 seismic recording amplifiers and pulse width modulators along with a magnetic recording drum. The recording amplifiers are broad band (7-350 cps) and are equipped with only as much amplitude control as is necessary to stay within the dynamic range of the recording medium. This is accomplished through the use of a fader, or suppression control, which may be set up to provide an attenuation vs time program to account for the variable energy level appearing at the input of the amplifiers. In addition, each amplifier is provided with an automatic gain control to compensate for the difference between the actual energy pattern and the pre-set attenuation program. The outputs of the recording amplifiers are pulse width modulated prior to being impressed on the magnetic tape. The modulation system utilizes a symmetrical 800 cps square wave carrier signal which fully saturates the magnetic tape. Modulation of this carrier consists of upsetting the time base symmetry in proportion to the amplitude and sense of the modulating signal. This type of modulation is very simple to accomplish and can accommodate modulating signals over wide dynamic ranges (46 db signal to noise ratio is consistantly maintained in this equipment). The most important asset of pulse width modulation, however, lies in the fact that the fidelity of the demodulated carrier is unaffected by amplitude disturbances such as external magnetic fields, poor head contact on the tape, etc., since the information is stored in terms of time relationships only. The amplitude of the carrier on playback may vary over a wide range without in any way deteriorating the demodulated signal.

†Electro-Tech Laboratories, Houston, Texas.

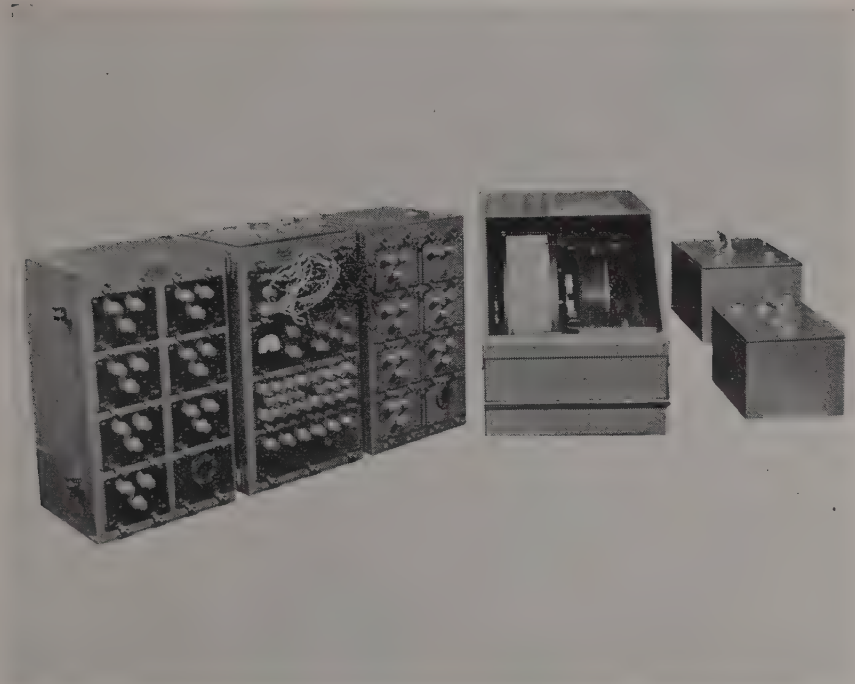


FIGURE 1. FR-1 Field Recorder

For field monitoring of the tape recording, an electro sensitive paper drum turning in unison with the magnetic tape drum is employed. A single pen motor and electro stylus displays each channel of information sequentially until all channels are played back. The pen moves over a space for each successive trace, resulting in the production of a monitor record closely resembling a conventional oscillograph record except that the process is entirely dry, requiring no chemicals or dark-room for developing. The main advantage of the sequential playback system, however, is the fact that only one demodulator and playback amplifier is required to playback any number of channels of recorded data.

The Office Playback System — The purpose of this machine is to process the magnetic tapes obtained with the field recorder. Contained in the machine are the necessary electronic and mechanical devices for performing the following data reduction functions:

1. *Static Time Corrections* — Weathering and elevation time corrections may be introduced on each trace individually.
2. *Normal Moveout Correction* — The time errors on traces due to the geometry of the spread may be corrected.
3. *Shot Mixing* — As many as four separate field tapes may be added in any of various mix programs available. The mixing may be accom-

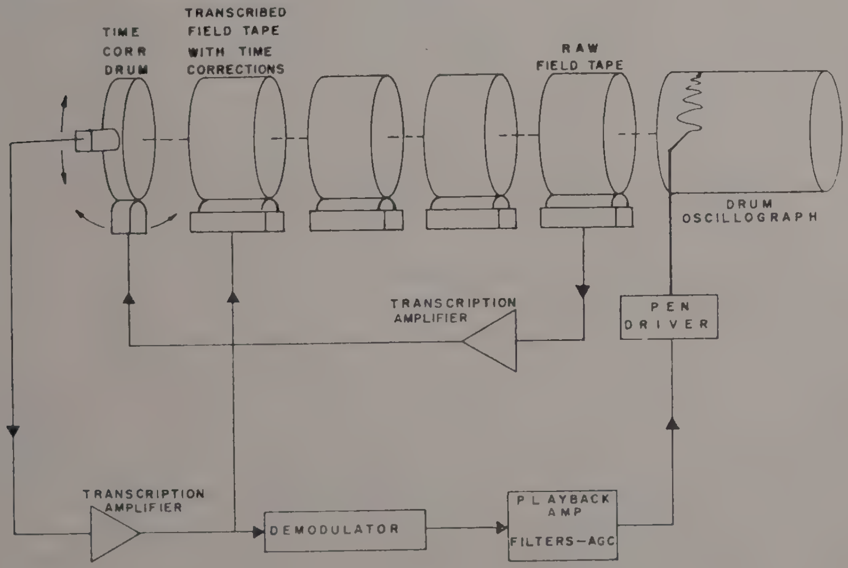
plished either before or after filtering and AGC.

4. *Cross Section Plotting* – The time corrected, filtered and mixed traces may then be displayed on an integral drum oscillograph, which utilizes either the dry process paper and stylus, as used in the field recorder, or a conventional mirror galvanometer with photographic paper. The trace spacing is adjustable, allowing up to 250 traces on 16" wide paper.

FIGURE 2. MT-4 Office Playback

The Office Playback Machine consists essentially of seven drums mounted in line on a rigid support frame. The left hand set of drums includes four standard tape drums and a single trace time correction drum. These drums are driven by a synchronous motor and are connected to a drum oscillograph and time break alignment drum through a three speed gear box. The electronic circuits required for automatic switching, demodulating, filtering, mixing, etc., are located in chassis below the drum bed. Each of the standard tape drums is equipped with a full set of 30 recording heads that are mounted in the same manner as the heads on the field recorder.

Time Corrections (See Fig. 3) – The first step in processing a field tape is to introduce the time corrections necessary to put all traces in their correct time relationship. This is accomplished through the use of a magnetic delay system consisting of a single track magnetic drum on which are mounted two movable magnetic heads. Since the playback is executed one trace at a time, only one of these systems is required. In practice, a field tape is mounted on one of the standard tape drums, which is adjustable with respect to the shaft in order to align the time break on the record with the mechanical index of the machine. This is actually accomplished by playing back the time break and displaying it on the time break alignment drum, on which is also displayed the mechanical index of the machine. When this adjustment is made, the field recording is then played back one trace at a time into the time correction system and transcribed on another drum as time corrected data. The time correction system functions as follows:



TIME CORRECTION PROCEDURE

FIGURE 3

1. Prior to the playback of each trace the static time correction is introduced by advancing or retarding the recording head on the time correction drum an amount (in milliseconds) indicated on the dial of the crank used to make this adjustment.

2. The dynamic time correction for each trace is accomplished by causing the pick off head on the time correction drum to move in such a manner that the $\triangle T$ vs t function is cancelled. Fig. 4 illustrates the mechanism which geometrically solves for $\triangle T$ and displaces the pick off head the correct amount as each trace is played back. The vector d/v is cranked into the mechanism prior to the playback of each trace.

$$\boxed{\triangle T = \sqrt{t^2 + \frac{d^2}{v^2}} - t}$$

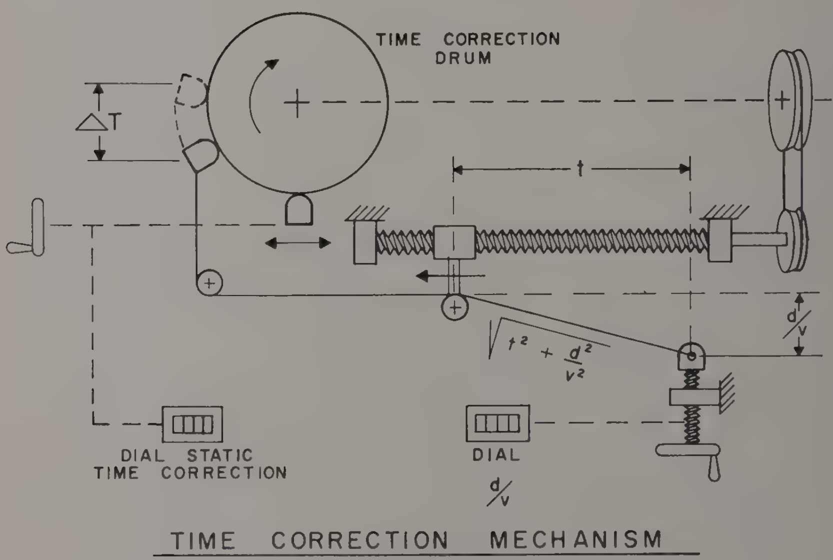


FIGURE 4

Compositing (See Fig. 5) — Up to four time corrected records can be composited simultaneously. Four demodulator channels are available, and by appropriate setting of the switching circuits, any four traces on either or all four drums may be simultaneously demodulated and mixed by either of ten available mix programs. Two playback amplifiers are provided, allowing the mix products to be filtered and AGC applied. These filters are identical to those in the FR-1 playback amplifier. The output of these two playback amplifiers may be further mixed and their sum fed to the drum oscillograph. If only three records are composited, their mix product may be converted to

pulse width data and recorded on the remaining tape drum to obtain a reproducible record which may be later mixed with another similar tape record. The number of methods for compositing then, is limited only by the operator's imagination.

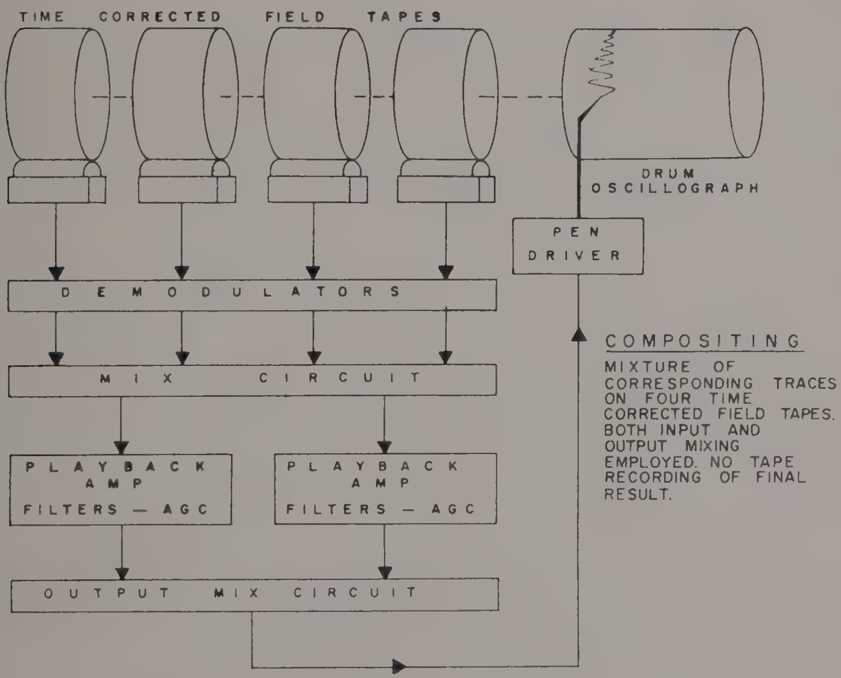


FIGURE 5

SEISMIC EXPLORATION IN THE DELAWARE BASIN

An Organized Approach to the Problems of a "Difficult Record Area"

by

M. E. Trostle†

For many years the Delaware Basin of West Texas and southeastern New Mexico has been indicated with a mental question mark on the maps of major and independent oil companies alike. That potential production and possibly even prolific reserves lie within the basin appears to be agreed on by all those who are hunting for petroleum provinces. Guideposts toward viewing the pre-Permian potential of the unexplored Delaware Basin region include the Puckett field of Pecos County, Texas; the Bell Lake field of Lea County, New Mexico; and the Toyah gas field of Reeves County, Texas. Whatever its oil-producing potentialities, however, the Delaware Basin has raised exceptional stumbling blocks to its development. Since the 1930's, many major oil companies have attempted seismograph operations in their particular areas of interest within the Basin. Their results were generally poor, and the net opinion was that only a few isolated areas could be considered as workable with the seismograph. Moreover, drilling costs ran high, and interest faded as deep tests encountered the thick Permo-Penn shale section.

Despite the stumbling blocks to successful exploration, however, there has been recently a rejuvenation of interest in the deep, but probably prolific, Delaware Basin. This rejuvenation of interest has been brought about in part by the tight land situation in the more highly developed areas of the United States and in part by the increasing demand for petroleum products, with the concurrent need for discovering more domestic reserves.

Renewed interest in the Delaware Basin causes geophysical exploration to face again one of its long-standing problems, for the Basin has continued to remain the Nemesis of seismic explorers. The problems exist for both refraction and reflection seismic surveys.

The character of the rocks and their great depth present a major difficulty to the use of the refraction method, which might be employed for large scale reconnaissance work. The Ochoa Series of the Permian consists of dolomites, anhydrites, and salts (below the top of the Rustler) which are characterized by high velocities. Interval velocities in these formations have been observed to be more than 22,000 feet per second. Interval velocities through the Delaware Mountain group are generally lower, but another velocity increase is then found in the Leonard. Average velocities increase generally to the top of the Wolfcamp, and then decrease because of the low-velocity Wolfcamp section. This thick, low-velocity formation lies unconformably on the pre-Permian rocks which generally consist of the

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normal sequence found on the Central Basin Platform and the Midland Basin. With these conditions in existence, recording refraction arrivals from Devonian or Ellenburger zones, using conventional techniques, would appear to approach the impossible.

In any event, the reflection seismograph is the tool of primary value for obtaining the data that will be required in the full exploration of the Delaware Basin. More money has been expended in the Basin on the reflection method than on any other geophysical method. The method has been used both experimentally and in production shooting and with the advent of multiple hole shooting and the use of multiple seismometers, portions of the Basin were made to yield usable seismic information, but as a whole the Delaware Basin remained to geophysicists an enigma characterized by poor records.

Why are the results from the reflection seismograph so poor in the Delaware Basin?

A preponderance of evidence indicates that the primary problem hindering successful shooting in the Basin lies in the presence and dominant character of near-surface refracted and reflected "noise" produced by the shot.

An early investigation into the noise problems of the Delaware Basin was made public in 1954 by Dobrin, Lawrence, and Sengbush.* In this paper, descriptions of various noise wave trains and their origins were of particular interest.

To obtain seismic information of usable quality in the Delaware Basin, then, suggests that an organized approach must be made to a study of the noise conditions in each prospect area in which the reflection seismograph is employed. With information on the nature and characteristics of the interference predominant in local areas, the geophysicist should then be able to design and employ seismic techniques which may enable him to penetrate the interfering noise and resolve usable reflection information.

In order to ascertain early in a seismic survey whether the area is within the range of possibilities for successful shooting, investigations have been made recently, under field conditions, into the benefits which can be expected from specific techniques and tools. These studies are helping in deciding upon avenues of record improvement, and are especially beneficial in limiting experimental time.

It is intended that the remainder of this paper will illustrate how knowledge of noise characteristics aids the geophysicist in using presently available tools to combat noise problems. Although illustrations used here are from work conducted recently for the TXL Oil Corporation in the Delaware Basin, they can equally be considered examples of an approach to seismic work which can be beneficial in numerous areas where similar problems confront the geophysicist. Analysis of record quality problems through noise

*M. B. Dobrin, P. L. Lawrence, and R. Sengbush, "Surface and Near-Surface Waves in the Delaware Basin," *Geophysics*, October, 1954, Vol. 19, No. 4, pp. 695-715.

studies has guided the development of seismic techniques in such virgin exploration areas as Australia, Libya, the Arabian Peninsula, as well as in the United States.

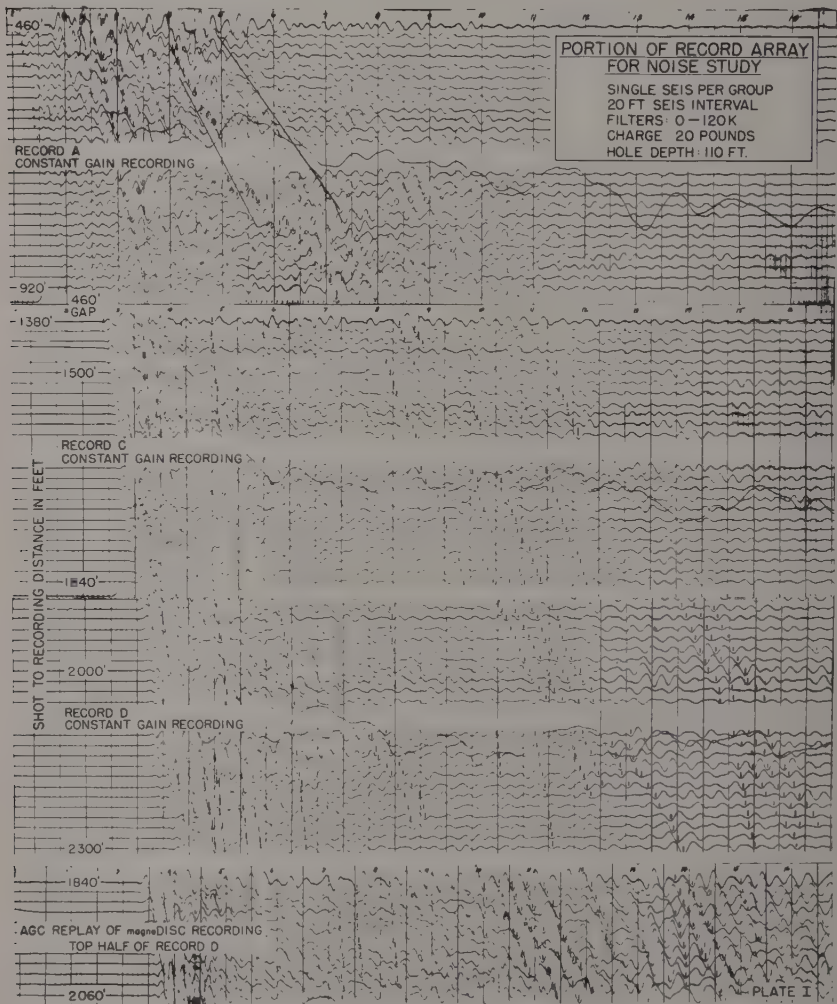


Plate 1

Plate I contains examples of seismograph records from a typical noise study. The records shown were recorded from a configuration utilizing one geophone per group and one shot-hole. Group interval is twenty feet and several shots were required to increase coverage of the spread to more than 3000 feet. Data shown were recorded magnetically with fixed gain ampli-

fiers. Fixed, or constant, gain recording allows accurate measurement of amplitudes; the reproducibility of magnetic recording allows later AGC replay as required.

From the records made with the noise spread, the following data can be obtained:

1. Frequency and amplitude characteristics of noise as a function of offset distance.
2. Signal-to-noise ratio variation with offset.
3. Apparent wave length of coherent noise waves.
4. The level of random noise and its position on the spread.

The direction in which noise arrives at the geophone can be determined by recording from spreads in which a short noise array of geophones is placed at right angles to the line of profile.

Data from these noise study records may be used in evaluation of various shot depths. Plate II-A shows how signal-to-noise ratio vs. charge depth may be plotted. The records will also yield information on rate of amplitude decay of a noise wave with offset distance, as shown in Plate II-B.

By first defining the noise problem in a local area, a logical approach to shooting the area can be made. A seismic field party equipped for operations in West Texas usually will have a number of variables which it can control. Such variables include multiple geophones, multiple holes, offset distance, filter cutoff frequencies, filter attenuation rates, explosives type and amount, hole depth, mixing, and magnetic recording.

In practice, the design of multiple geophone arrays is controlled by: (1) wave length of noise, (2) dip and normal moveout expected, (3) direction noise arrives at geophone group, (4) amount of random noise, and (5) terrain.

These factors, together with the additional factors of pattern-hole costs and effect of hole depth on noise and signal, can control the design of multiple-hole patterns.

Value of offset spreads can be predicted from analysis of the noise study. In an area such as that in which the records shown in Plate I were shot, it would be inadvisable to use "broadside" offsets because the noise events, in particular the higher velocity events, would line up and give the appearance of reflection events.

Filter settings are determinable by study of the reflection frequencies. Difficulties may arise when many of the noise events are very close in frequency to the reflection frequencies. In selecting filter attenuation rates to be used in conjunction with magnetic recording, it is important to recognize the possibility of overloading the system with low frequencies where strong noise events of low frequency may exist.

Mixing can be used to improve the signal-to-noise ratio under certain

conditions. The controlling factors are generally the variations in weathering, the amount of normal moveout and dip, the spread length, the group length, and the changes in elevation. In general, it would appear that a small amount

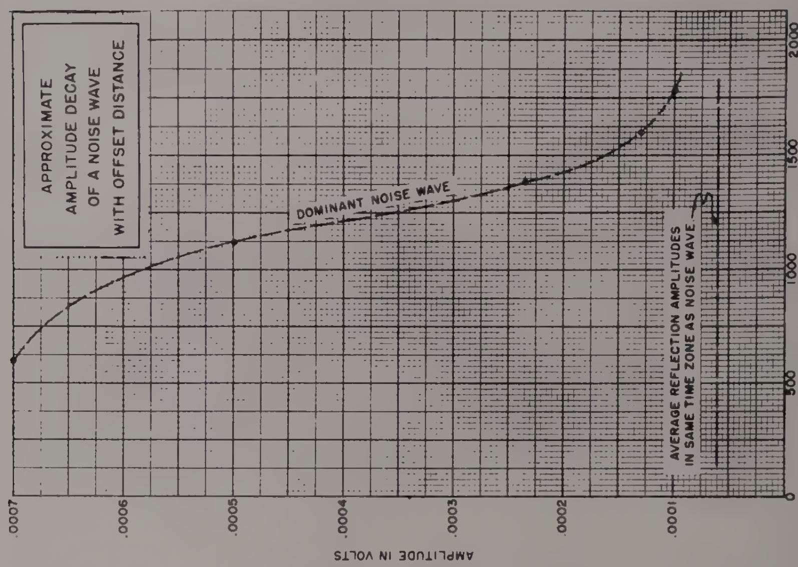


PLATE II-B

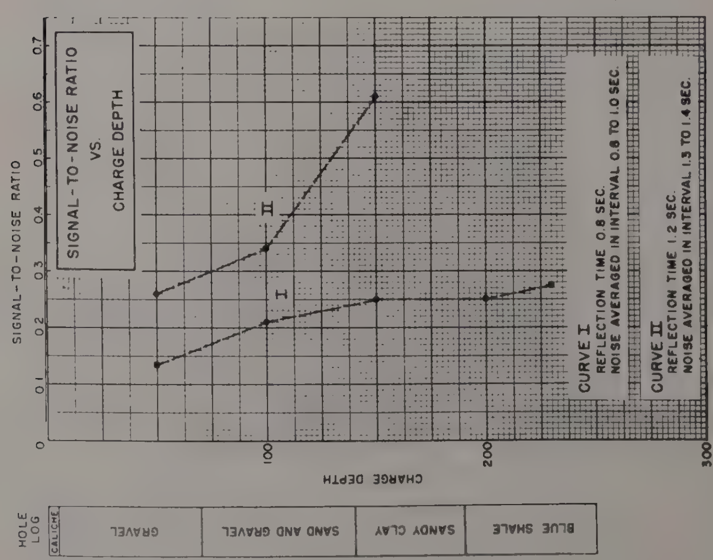


PLATE II-A

of mixing is not objectionable for most of the Delaware Basin, but weathering and dip limit the use of "taper" mixing. Also, in mixing of the resistance type, such as the taper mix, a strong noise event could affect a large portion of the record.

Magnetic recording techniques are desirable in the Delaware Basin because of difficulties encountered in re-loading holes for repeat shots. Pattern holes drilled with air are usually dirted after one shot. Selective filtering has been advantageous in some areas.

The new "sausage" dynamite has also been used to advantage in some areas. Plate III shows a comparison of three shots from the same location. The bottom record was recorded from geophone groups of 24 geophones per group, in line, with the shot fired in a single hole. The two records at the top of the plate were made following a noise study and redesign of the geophone spread.

From the noise analysis it was found that the interfering noises had the following characteristics: at short distances the noise was complex and generally random, but had strong side components, indicating the necessity of a radial coverage of geophones; strong coherent noise interfered with the reflected energy in the .4 to 1.0 second portion of the record for groups beyond 900 feet and traveled in a direct line from shot to detector; in the 1.5 to 2.1 second portion of the record, random noise was predominant, and most of the coherent noise traveled a direct path from shot to detector; coherent noise attenuated rapidly with distance; and noise character and reflection character were similar over a wide range of hole depths.

Under these conditions, the number of geophones per group was increased from 24 to 48 in an effort to combat random noise, and the geophone group was laid out to cover a large area to aid in eliminating offside coherent noise. Shots were taken at the hole depth indicated as optimum.

With this configuration, the center record on Plate III was obtained. Improvement in the shallow portion of the record near the Delaware reflection (.7) was shown, but additional improvement was needed in the groups near the 1000-foot distance where coherent noise was particularly strong.

The use of a long column of powder was considered, and from the travel paths of the coherent noise events it was believed that improvement in noise attenuation would be found for the first 1500 feet of the spread by using a column of powder 170 feet long. This charge was loaded and fired and the record at the top of Plate III was obtained. In the illustration shown here the total dynamite charge varies from record to record and could be considered a contributing factor in the variation of results; however, other tests indicated that the total charge was not critical in elimination of noise.

Lines drawn on the records show the path of coherent noise wave trains as obtained from analysis of the noise study records. Note how the interference patterns terminate reflections on the bottom record.

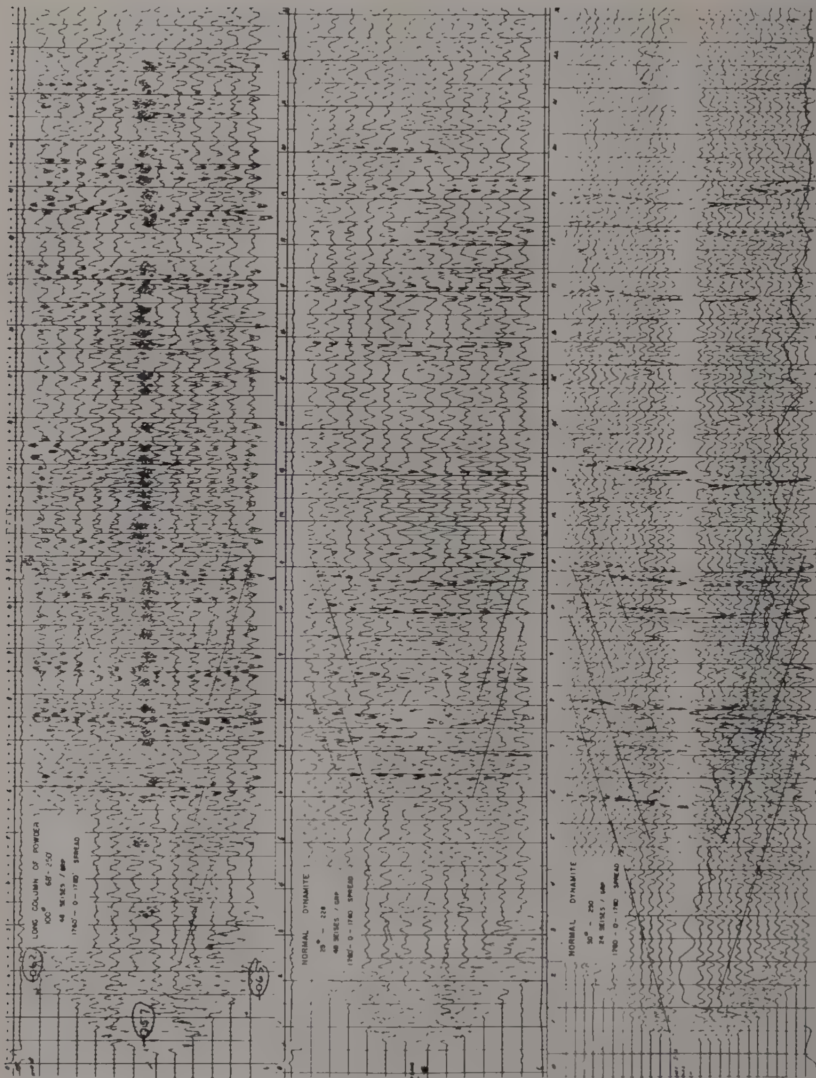
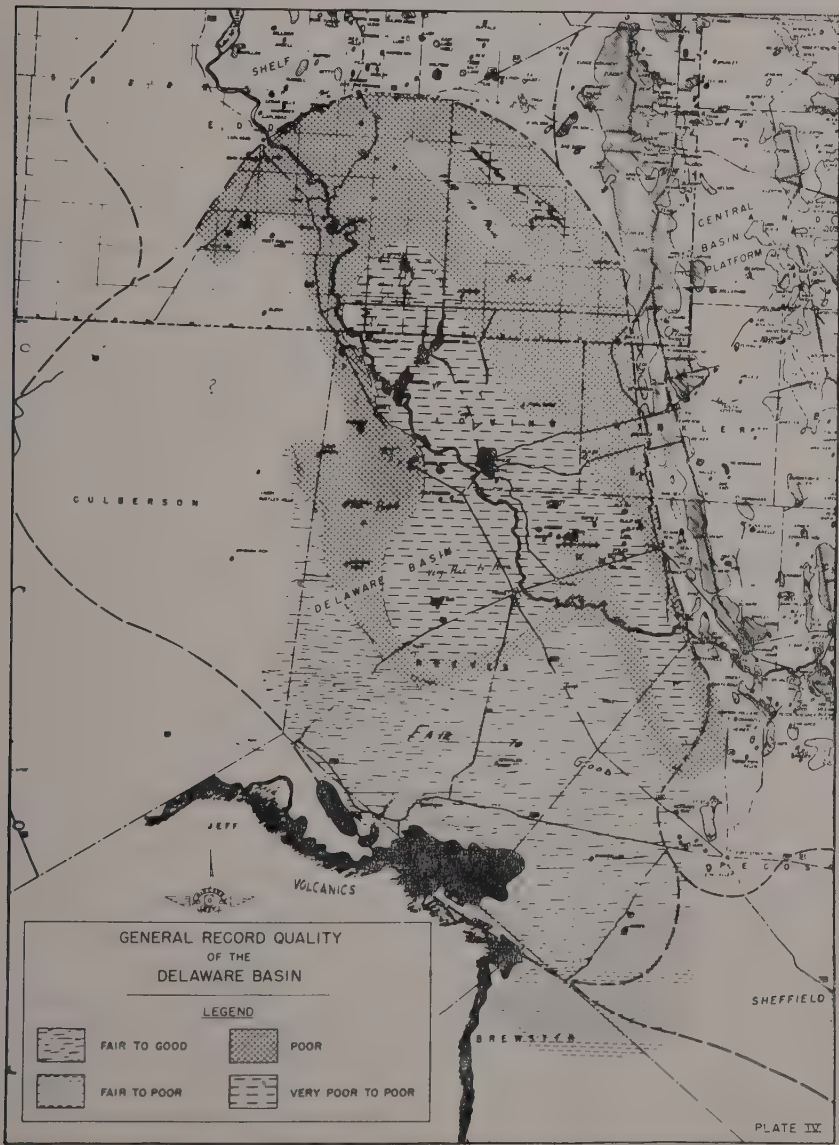


PLATE III VARIATION IN RECORD QUALITY WITH CHARGE TYPE AND NUMBER OF SEISES PER GROUP

Noise studies and analyses made recently in the Delaware Basin make possible the construction of a generalized record quality map of the Basin for the area east of the Culberson County line. This generalized record quality map is shown in Plate IV. The poorest record quality follows to some extent the path of the Pecos River. Thick zones of unconsolidated material typlify most of the area, and noise problems are severe. Other very difficult areas include the swales, such as the San Simon swale in Lea County, New Mexico, where salts have been replaced by fill material. The southern and

southwestern portions of the Basin are shown to be less troublesome. The eastern half of this better zone has a high velocity near surface. The western half contains a great deal of gravel and clay.



Although the record quality map is fairly well controlled, it should be emphasized that within each of the various zones a radical change could be found for isolated areas. The map itself has been prepared to demonstrate that the possibilities of shooting the Delaware Basin should not be based entirely on experience in one location alone.

Not all of the problems of the Delaware Basin will be solved by obtaining recognizable and correlatable reflections, but to obtain these reflections is a primary problem which must be solved before the Basin can be opened for production seismic work and for the evaluation of its oil-producing potentialities.

It is believed that the organized application of shooting techniques, directed by results of careful studies which indicate how the interfering noise may be penetrated, makes it possible to use the reflection seismograph in mapping much of the Delaware Basin with techniques now available.

GEOPHYSICAL CASE HISTORY
of the
ENGEL POOL

by

Lee Brooks, John Care, Charles Wallace†

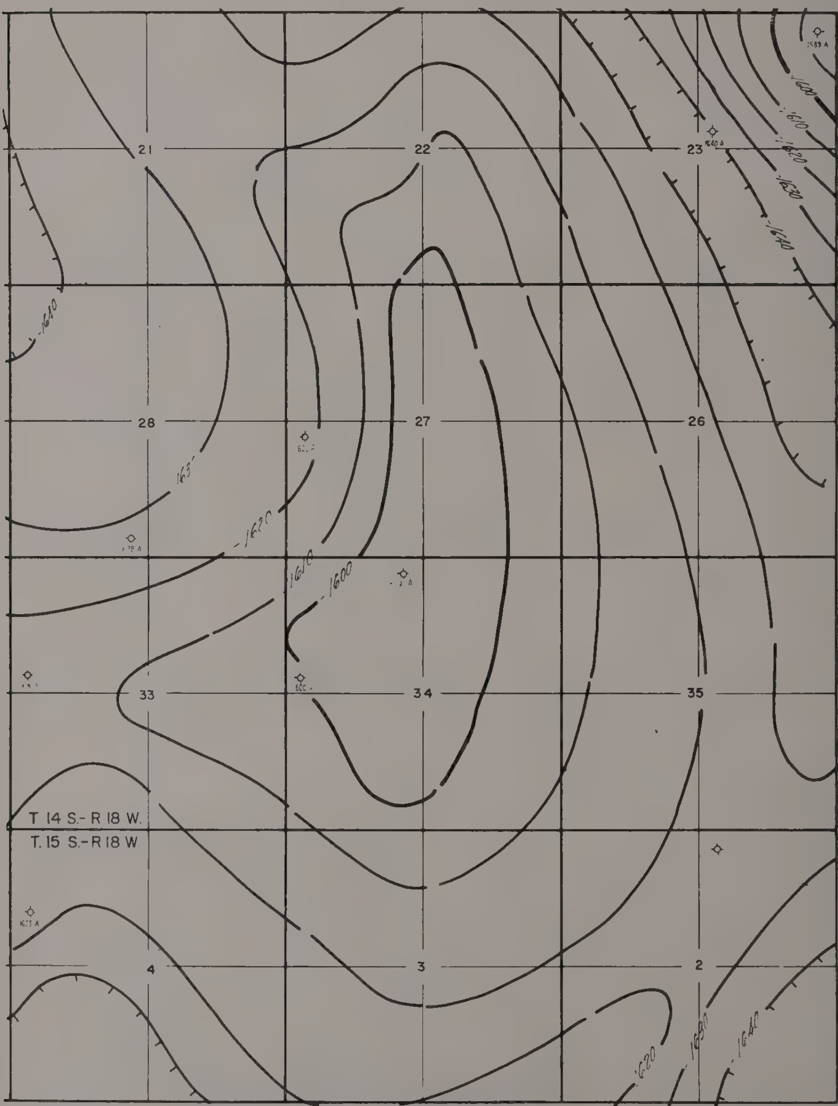
The Engel Pool is located five miles east of Antonino, Kansas, in Section 34, Township 14 South, Range 18 West, Ellis County. This pool is selected for this paper because it is illustrative of the advantages of the seismic method of exploration on the Central Kansas Uplift.

A seismic survey was conducted on this prospect because the sample analysis on the old dry hole located in the NE NE NW of Section 34 indicated that this dry hole was very near production. It was the client's opinion that this possible productive area was to the south of this dry hole. Figure 1 is a subsurface map contoured on the top of the Arbuckle limestone from well information available in October 1955. The seismic survey was intended to check this subsurface lead. Upon deciding that the record quality was good enough to permit mapping a 25 to 30 foot closure, it was decided to proceed with the survey. The pattern of control was laid out on a diagonal 20-acre grid pattern as shown by Figure 2. This control pattern was used because it was believed that the over-all probable error on the maps would be decreased by increasing the density of control. In other words, a more thorough evaluation of the geophysical interpretive problems could be made with additional geophysical data. Another reason for the dense control was the possibility that the areal extent of the anomaly or anomalies could be quite small. Therefore, it can be seen that both the geologic and the seismic problems were considered in laying out the control pattern.

The spot correlation method, utilizing an 8-trace, triple recorded, single end spread, was used on this prospect. Shooting technique, based on past experience in the area, was used to obtain generally good records. The fact that the records were triple recorded was important because it made it possible for the interpreter to study three different types of instrumental filtering on each shot. Therefore, it was possible to do a fairly complete job of analyzing the character changes and, in general, their cause.

It is to be noted that only isotime maps are used on this prospect. Figure 3 is a map based on the isotime between the Anhydrite and an Upper Pennsylvanian reflection. The map depicted in Figure 4 is based on the isotime between the Anhydrite and a reflection emanating from the unconformity between the Pennsylvanian and the Ordovician. One reason for the use of isotime maps, rather than the conventional seismic structure maps, was to eliminate the errors caused by near surface velocity variables. Further, it was the consensus of poinion that an isotime map between the Stone Corral (Anhydrite) and the lower markers could be used for structural evaluation. This was based on the geologic premise that thinning of section is coincident with structural highs in this area.

†Seis-Tech Exploration Co.



Approximate Arbuckle Subsurface Map

Figure 1

Referring to the isotime maps (Figures 3 and 4), it is apparent that shot point 3 (NE SE NW Section 34) is in the center of a small anomaly. This point was the initial drill site recommendation. It was drilled and found to be productive in the Lansing and Arbuckle formations. Subsequent drilling on the diagonal northwest and northeast offsets to the discovery well were

found to be productive in the Lansing formation. The southeast offset to the discovery well is also productive in the Basal Pennsylvanian sand. A test was then drilled at shot point 2 (SW SE NW Section 34) and was 13 feet

Figure 2

lower at Lansing level than the discovery at shot point 3. The Arbuckle datum was quite low, indicating that the test was on the flank of the high, and encountered a very sharp erosional low typical of the area. This low was indicated on the maps by 2 to 4 milliseconds of thickening.

In conclusion, this paper indicates the value of the seismic method, properly used, for the detailed evaluation of subsurface ideas on the Central Kansas Uplift. Subsurface geology is necessarily very general because of the lack of control and the existence of a severely eroded surface on the top of the Arbuckle. The additional control needed is made available by the reflection

seismograph, and the pattern of erosion on the top of the Arbuckle is indicated, in general, on the Approximate Unconformity map. Density of control is necessary because of the small size and low relief of the structures, and the fact that the seismic problems are magnified by the low structural relief of the prospective anomalies.

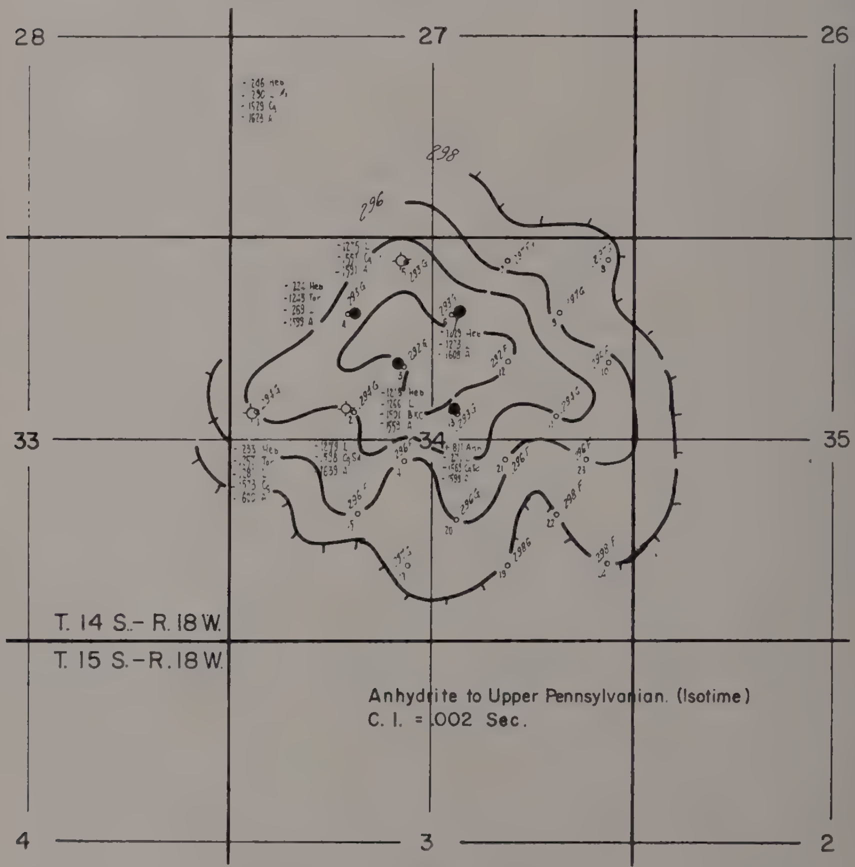


Figure 3

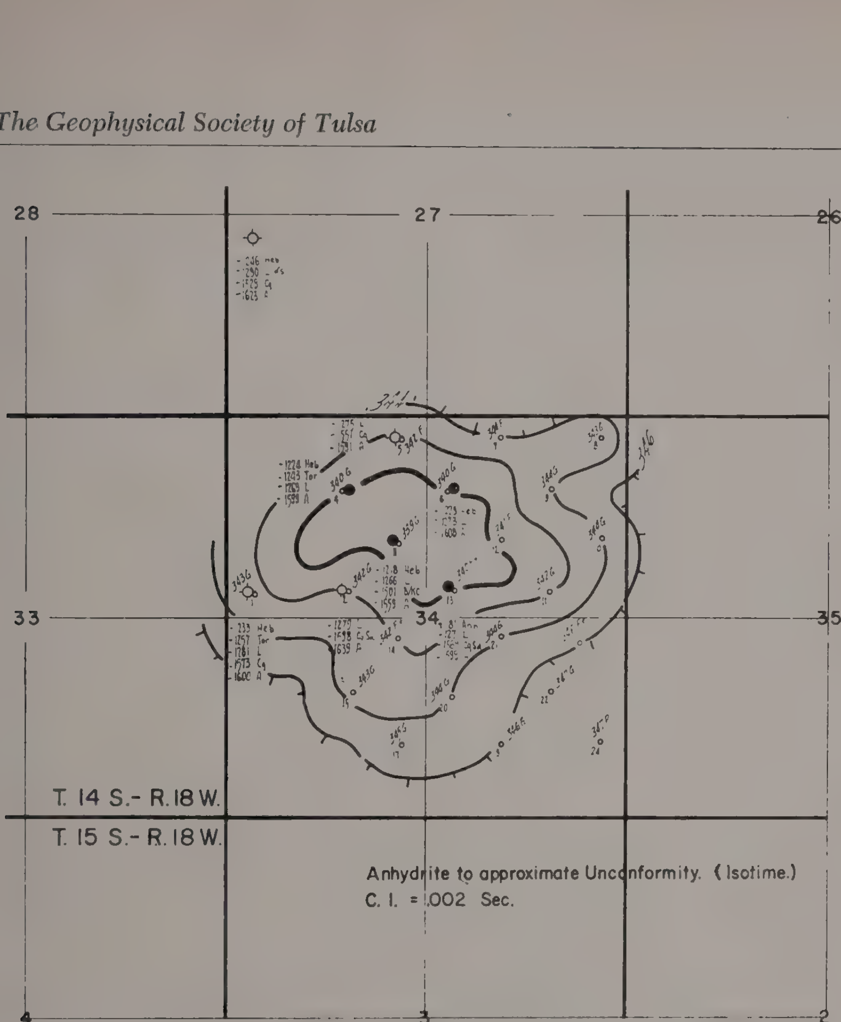


Figure 4

ACKNOWLEDGEMENTS

The Engel Pool was discovered and developed by the Colorado Oil and Gas Company. The authors hereby express their appreciation to the Colorado Oil and Gas Company for permission to publish information presented in this paper, and to Messrs. D. G. Benson, Stewart L. Carter, Arthur W. Deaver, and Jack L. Yinger for their able help and suggestions in the preparation of this paper.

HIGH RESOLUTION SEISMIC EXPLORATION NORTHEASTERN AND NORTHCENTRAL OKLAHOMA

by

R. F. Van Cleave

Early in 1955 work was started on modification of a set of conventional seismic instruments for high frequency recording. Interest in the higher parts of the seismic spectrum had been stimulated by results reported by Allen et al, 1952,[1] and Pakiser, Mabey and Warrick, 1954[2]. The specific application of interest was the exploration of shallow producing areas not previously considered susceptible to conventional seismic techniques and detailed mapping of deeper areas where low relief or complex structural conditions required higher resolution of the seismic reflections.

All development work and field tests were carried out jointly by the author and C. P. Durant, partners in Interstate Exploration Company.

Instrumental modifications consisted of the addition of high filter ranges, reduction of the AGC time constant by approximately 50 percent and a change in the paper drive mechanism to permit paper speeds up to 24 inches per second.

Early field tests indicated that filter pass bands between 85 and 140 cycles per second were best suited for the depth range from 1000 to 5000 feet. In the areas sampled the sedimentary section varied from a thickness of approximately 2500 feet in central Wagoner County to approximately 5000 feet in western Pawnee County. Areas sampled during the experimental stages of instrument modification included the following –

Township 18 North, Range 16 East, Wagoner County

Township 17 North, Range 16 East, Wagoner County

Township 16 North, Range 16 East, Muskogee County

Township 17 North, Range 14 East, Tulsa County

Township 19 North, Range 13 East, Tulsa County

Township 17 North, Range 13 East, Tulsa County

Township 16 North, Range 8 East, Creek County

Township 28 North, Range 8 East, Osage County

Township 23 North, Range 3 East, Pawnee County

The results of one of the first surveys made with the high frequency equipment are shown to illustrate the amount of detail which can be obtained in

localizing the small, low relief structures typical of the shallow producing areas of northeastern Oklahoma.

The area is located in southeastern Tulsa County, Section 21, Township 17 North, Range 14 East. A portion of Dillés map of Tulsa County[3] contoured on the top of the Mississippian Lime is reproduced in Figure 1 to show the

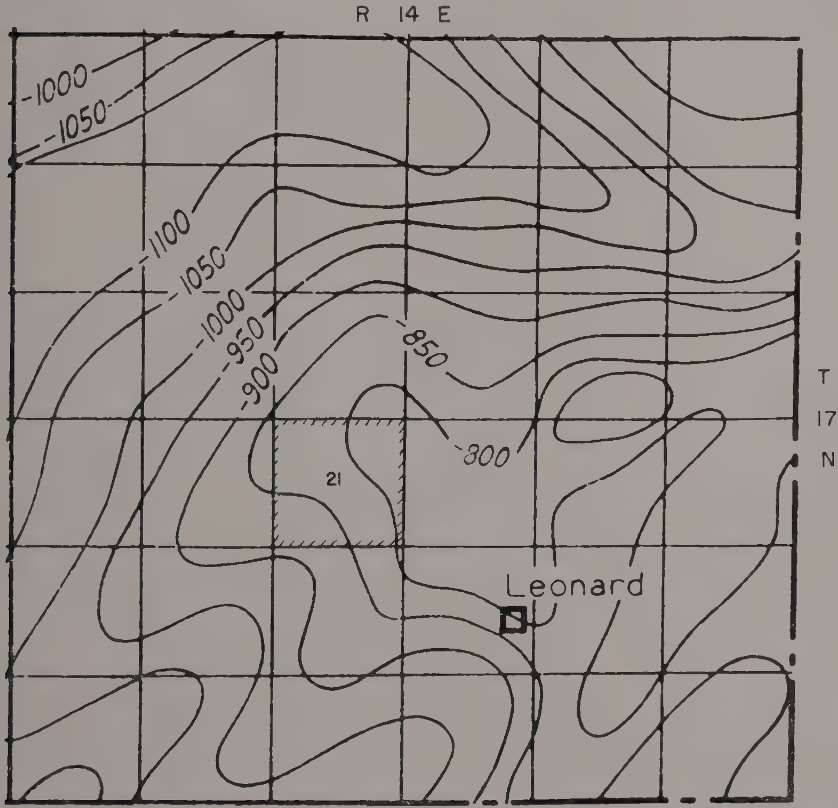


Figure 1

After Dille, Map of Tulsa County, Oklahoma. Contours on Top of Mississippian Lime. C.I.: 50 ft.

regional setting. Sketchy formation control from cable tool driller's logs indicated some abandoned lower Simpson producing wells in the east half of the southwest quarter of section 21 to be located on a southwestward trending nose. These wells were drilled about 1916 and no reliable logs or production data were available. Two dry holes had been drilled to the Arbuckle Lime since 1950, the Midcontinent No. 1 Porter in NW-SW-SE 21 and the Midcontinent No. 2 Porter in NE-SW-NE 21. A small show of oil had been encountered in the Burgen (lower Oil Creek) sand at the No. 2 Porter well and this was the reason for initiation of seismic work on the prospect. Twenty

points were shot in the northeast quarter of the section and verified a southwestward trending ridge through the No. 2 Porter well with about 20 feet of east-west turnover. However no point higher than the No. 2 Porter well was located at that time and the prospect was temporarily abandoned. At a later date it was decided to extend the survey southwestward to check the structural position of the abandoned producing wells in the southwest quarter of the section. The results of the completed survey are shown in Figures 2

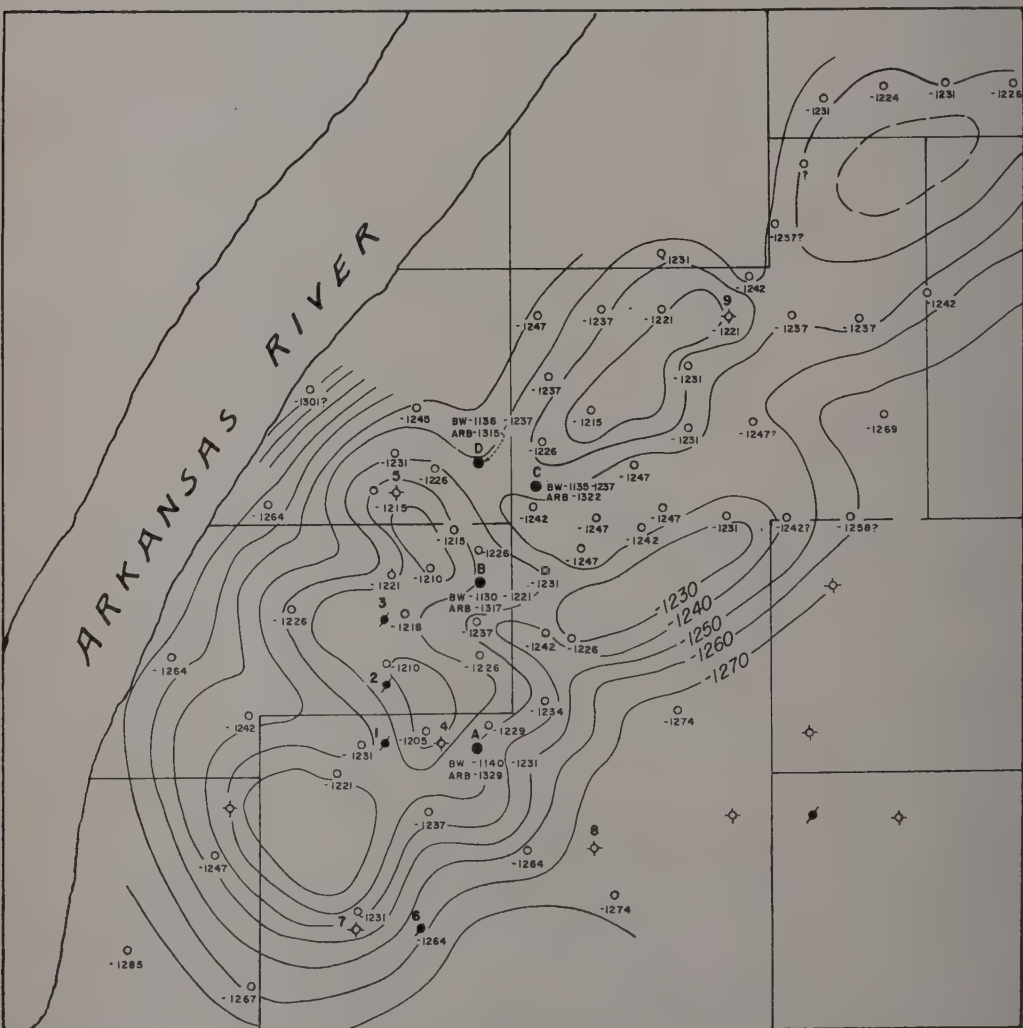


Figure 2
Seismic Control Data for Top of Simpson Formation. Sec. 21, T 17 N, R 14 E, Tulsa County, Oklahoma.
C. I.: 10 ft.

and 3 which show control for the Simpson and Arbuckle formations.

The completed picture indicated that the structure had not been fully exploited by the original drilling and also strongly suggested that the old production was the result of a combination stratigraphic and structural trap. Development had been stopped to the east of the old discovery well

Figure 3
Seismic Control Data for Top of Arbuckle Formation. Sec. 21, T 17 N, R 14 E, Tulsa County, Oklahoma.
C. I.: 10 ft.

(No. 1 on maps) by a dry hole (No. 4 on maps). No log of this dry hole

was available. The seismic data showed the dry hole to be 25 feet higher than a shot point 250 feet east of the dry hole and 25 feet higher than the discovery well, 300 feet to the west. It was assumed that the sand had been missed in the dry hole, either because of non-deposition at the higher structural level or a facies charge associated with the abrupt dip. A drilling location (shown at "A" on maps) was made 250 feet east of the dry hole. The seismic data indicated this point to be at the same structural level as the discovery well. Twenty feet of limey sand was drilled in the Burgen section and the well produced at the rate of about 20 barrels per day, natural. The well was given a high speed "sand frac" and broke into water and was abandoned. The second location (shown at "B" on maps) was selected 850 feet north of the first well. The seismic data indicated this location to be 10 feet higher than the "A" location and on the east flank of the structural ridge. Fourteen feet of sand was encountered but the sand was tighter than at "A" and made only 20 barrels per day after shooting with 36 quarts of nitroglycerin. Gamma ray - Neutron logs of wells "A" and "B" showed "B" to be 10 feet higher structurally than "A" and the producing section to be less porous.

The third location was made at "C", about 600 feet northeast of "B". The seismic data indicated this location to be slightly lower than "B" and in a "saddle" on the main structural ridge, which was believed to make the location favorable for sand deposition. Twenty feet of porous sand was encountered at this location and the well produced initially at the rate of 100 barrels per day after shooting. The well was not logged but steel line measurements indicated the well to be 5 feet lower structurally than "B".

Lease obligations required a test in the SE-NW 21 and location "D" was selected as being in a similar position structurally to location "C", on the opposite side of the "saddle". The well drilled at "D" location found twenty-five feet of Burgen sand with apparently the best porosity of any of the four wells drilled. Steel line measurement at total depth showed the well to be six feet higher at the top of the Arbuckle than well "C". As this is written the well was in process of completion and was flowing intermittently through seven inch casing. The better performance of wells "C" and "D" than well "B" is attributed in part to their greater distance from the area depleted by the old production, but is believed mainly due to better sand development because of their structural environment in relation to the crest of the ridge. The high structural position of the dry hole at 9 on the map, northeast of the recently drilled wells, tends to confirm this.

This report is not intended as a "case history" since only four wells have been drilled and development is still in progress. The operators intend to continue to explore the flanks of the structural ridge, using the seismic picture as a guide to avoid the top of the ridge and place development wells in a structural position believed stratigraphically favorable on the basis of information gained from the wells previously drilled. Seismic interval maps may prove of value when enough drilling information has been obtained to correlate the results.

The results to date indicate that high frequency seismic work is a useful tool in mapping small low relief structures at relatively shallow depths and that the detail which can be provided is a definite aid in development drilling when structural position is one of the variables on which accumulation is dependent.

It should be emphasized that high resolution mapping as applied to the type problem presented here requires considerably greater density of control than is customary in conventional seismic exploration. The areal dimension of resolution, as well as the vertical, must be increased to obtain maximum benefit of the method.

The author wishes to thank Mr. Linn Shanks, oil operator of Leonard, Oklahoma, for his consent to publish the results of the survey. All development and field work involved in perfecting the high resolution equipment represents the joint efforts of the author and C. P. Durant, partners of Interstate Exploration Company.

REFERENCES

1. Allen, C. F., Lombardi, L. V., and Wells, W. M., 1952, "The Application of the Reflection Seismograph to Near-Surface Exploration," GEOPHYSICS, Vol. 17, No. 4, pp. 859-66

2. Pakiser, L. C., Mabey, D. R., and Warrick, R. E., 1954, "Mapping Shallow Horizons With Reflection Seismograph", Bull. Amer. Assoc. Petrol. Geol., Vol. 38, No. 11, pp. 2382-94

3. Oklahoma Geological Survey, Bulletin 69, "Geology and Mineral Resources of Tulsa County, Oklahoma" by Malcolm C. Oakes with section on Oil and Gas by Glen S. Dille

A COMPARATIVE STUDY OF THE VERTICAL GRADIENT OF GRAVITY

By

FREDERICK ROMBERG†

ABSTRACT

The usefulness of measuring the vertical gradient of gravity in the field is examined by studying examples. The resolving power of the vertical gradient due to a pair of point masses is compared with that of the horizontal gradient. No advantage for exploration purposes can be seen in determining the vertical gradient on the surface by reading a gravity meter at a station on the ground and on a high tripod.

INTRODUCTION

The anomalous vertical gradient has received much study since gravity began to be used as an exploration tool. Evjen (1936) and Ackerman and Dix (1956), as well as many others in between, have written on the subject. Most authors have been concerned with the process of computing vertical gradients from the gravity field as observed with a gravity meter. For instance, Selem and Monnet (1953) computed the vertical gradient from a map of the observed gravity from which the regional had been removed, and stated that, as would be expected, the vertical gradient showed the best resolution.

More recently, Thyssen and Stackler (1956) made actual observations of the vertical gradient in the field by reading a gravity meter on the ground and then up on a tripod 12.5 feet high at the same location. This method, the authors pointed out, has inherent physical difficulties because of the disturbance from vibration and the short vertical displacement it is possible to achieve without cumbersome apparatus.

It would seem to be much easier, from the standpoint of expense, time, and accuracy, to read the horizontal gradient by observing a gravity meter at three locations on the ground. The error inherent in the short distance between stations could be reduced in proportion by lengthening this distance. Any advantage inherent in studying the vertical gradient could be better realized by increasing the ground accuracy of the horizontal gradient and accelerations that are observed. The extra trouble of having to determine the relative elevations of the three ground stations (which could be done very quickly with a self-leveling instrument) would probably be less than the practical difficulties of erecting a high tripod and reading the meter on it and on the ground enough times so the required accuracy is achieved.

The purpose of this paper is to examine the above proposition quantitatively by considering simple tests for the main assumptions on which it is based. The relative resolving power of the vertical and horizontal gradient for two simple masses close together will be examined graphically. The effect of terrain irregularities and the effect of increasing depth on the perceptibility of gradients will be discussed quantitatively. The formulas which will be used are elementary and will be quoted at the end of the paper for reference.

†Geophysical Service, Inc.

RESOLUTION

The first logical step in studying the comparative powers of the vertical and horizontal gradients is to consider two anomalous masses separated by a short distance. For simplicity, the two masses will be assumed equal and at the same depth. They will be separated by a distance which is measured in terms of the depth, z. If the horizontal variation of the gravity gradient which results from one of the masses is computed, the total gradient of the two masses for any given separation of the masses can be found by adding one set of values to a similar set which is offset by the distance of the separation. The mass and the depth cancel out, so the treatment is valid for all concentrated masses, great and small, and for all depths with a proportionate separation.

Figure 1 shows the sum of the horizontal gradients, plotted against horizontal location, of two equal masses for separations of one-quarter, one-half, and three-quarters the depth. The horizontal gradient of a single mass is shown for reference. We expect, of course, to find that the sum will look like the gradient of a single mass when the masses are close together, and like two entirely separate curves when they are far apart. The point in between, at which they become (or cease to be) distinguishable, is defined as the limit of resolution. In actual exploration this point is necessarily subjective, as it can be read only from data of limited accuracy, observed at gross intervals and giving curves about which nothing is known except that they are not derived from regular spherical masses. The only practical way to tell the difference between a curve resulting from a single mass, and a curve which is the sum of two such curves is to find an extra point (or rather an extra pair of points) of inflection.

On Figure I the resultant curve for the separation $x = z/4$ is quite similar in shape to the curve for a single mass, or zero separation. The curve for $x = z/2$ is broader but this is a poor criterion in practice, as we do not know how deep or how concentrated the masses are. It is only on the curve for $x = 3z/4$ that we see the new pair of inflection points, which indicates a compound rather than a simple curve. For all practical purposes, therefore, the resolving power of the horizontal gradient begins at a point between $x = z/2$ and $x = 3z/4$.

Figure 2 is a similar set of curves for the vertical gradient. Offhand it looks as though this quantity would be a tool with higher resolution than the horizontal gradient because it is symmetrical instead of anti-symmetrical about the gradient axis. (There are two sides to this argument; if a small symmetrical anomaly — a "hump" — coincides with the apex of a larger "hump" the smaller one may be harder to see than if it were an anti-symmetrical anomaly or a "kink.") In any case, the vertical gradient anomaly for $x = 3z/4$ is still a single high; the sign of the curvature does not change and there are no new inflection points. The inflection points do not appear until somewhere between $x = 3z/4$ and $x = z$. The resolving power of the vertical gradient begins therefore at a point between $x = 3z/4$ and $x = z$.

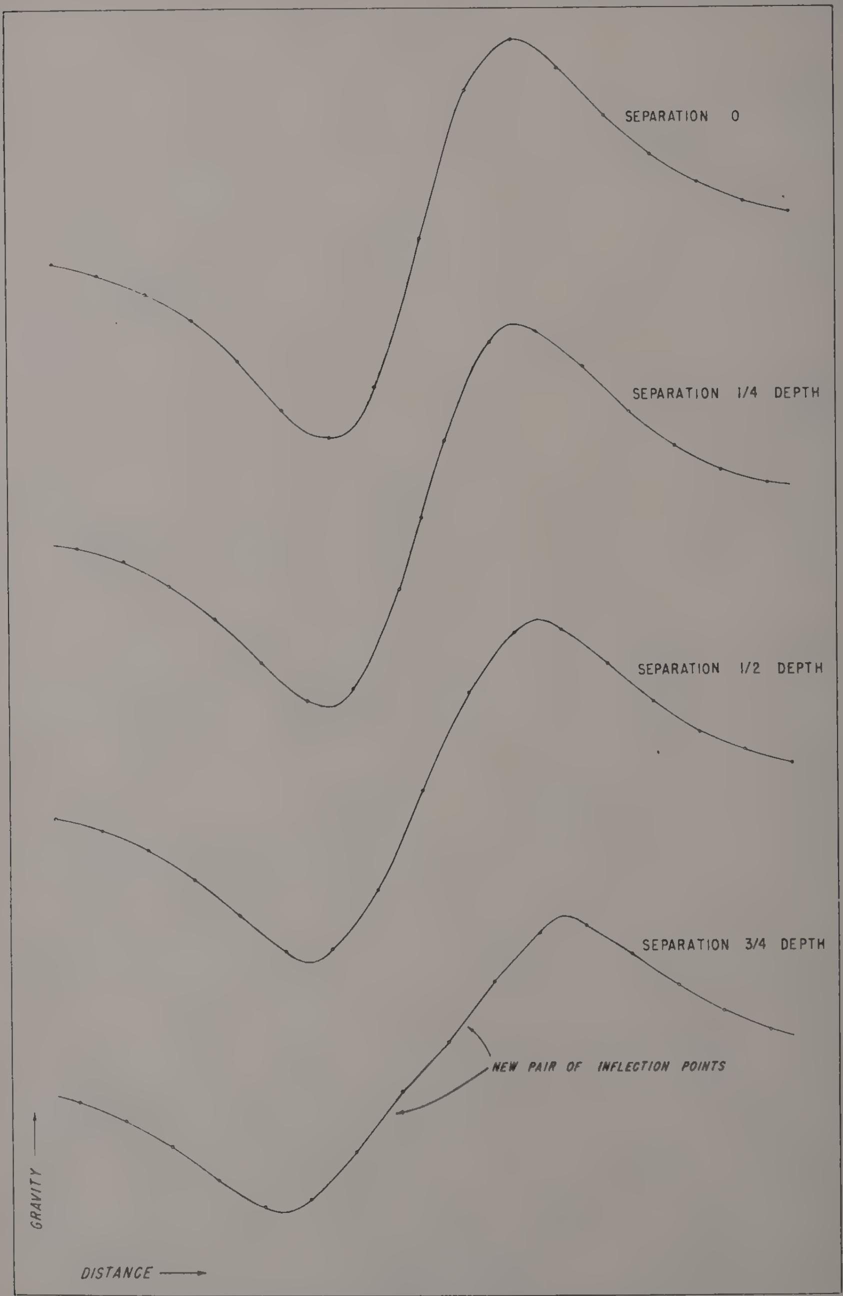


FIG. 1. Effect of separation on horizontal gradient due to separate masses.

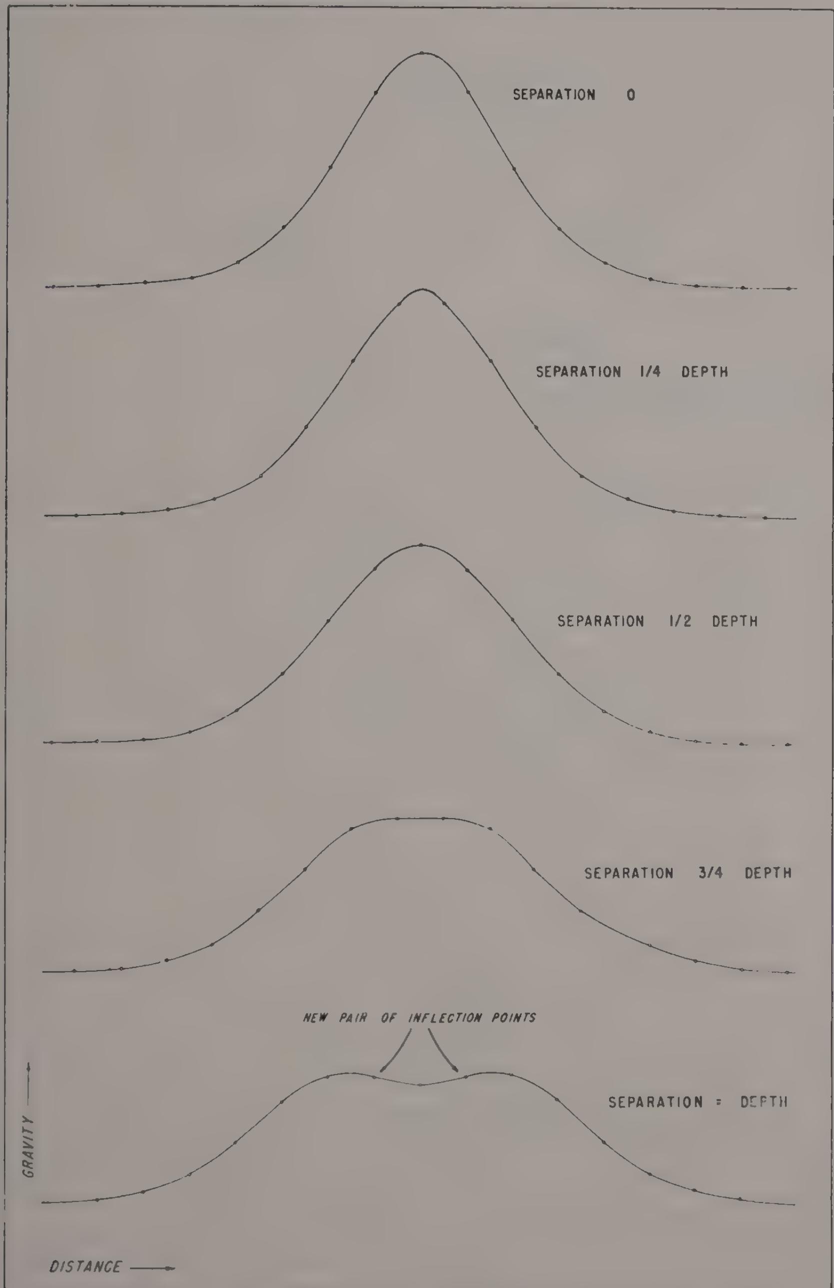


FIGURE 2. Effect of separation on vertical gradient due to separate masses.

This demonstration holds, of course, for a particular case only, though it is general as to scale. It is possible that analysis by higher derivatives might indicate resolution in the vertical gradient at less separation than in the horizontal gradient. Such analysis is beyond the scope of this paper. It should be remembered, however, that the higher the derivative the greater the effect of small errors in observation. Since by hypothesis we are working on a borderline of practicability, it would be difficult to prove that the benefit to exploration from measuring the vertical derivative directly outweighs the practical difficulty and reduced accuracy of the method, as compared to measuring the horizontal gradient.

Effect of Rough Terrain

One of the disadvantages of the torsion balance as an exploration tool was that it was much affected by small local irregularities in the terrain. The same disadvantage exists in measuring the gradients with a gravity meter, as the result is in the form of the difference between two quantities which are nearly equal. An error in a gravity determination which was caused by terrain might be too small for notice in a Bouguer map but important in a gradient determination.

It is appropriate to compare the error caused by local terrain in a gravity meter read on the ground with the error caused by the same feature in a meter read on a tripod. A low mound, say, in the neighborhood of the station will cause a negative error $-\Delta G_g$ in the ground reading, and a positive error ΔG_t in the reading on the tripod. Since the gradient is the difference between the two gravity readings the total error is $\Delta G = \Delta G_t + \Delta G_g$. In the case of a determination of the horizontal gradient we have $-\Delta G_g$ and $-\Delta G_g^1$, but as these have the same sign they act against each other when their difference is computed. In rough terrain this would be an important advantage for the horizontal gradient.

Incidentally, if the disturbing mass is low enough so that its center of attraction is less than half the tripod height, then its effect ΔG_t on the tripod reading would be larger than its effect ΔG_g on the ground reading because its vertical component would be greater. This points out an additional disadvantage of measuring the vertical gradient directly.

Effect of Depth

Evjen (loc. cit.) points out that the gradient has better resolving power than gravity. However, in exploring for deep structures this advantage is soon overshadowed by the effect of depth. It is well known that the magnitude of the gradient caused by a concentrated anomalous mass decreases with depth at a greater rate (inverse cube rather than inverse square of the depth) than the magnitude of gravity itself. One way to study the relative usefulness of the gravity gradient with respect to gravity itself would be to compute the depth at which an appropriate mass would give the smallest anomaly observable by each method. If we assume that gravity can be measured on the ground to ± 0.02 milligal, and that the gradient can be

measured (Thyssen and Stackler, loc. cit.) by the tower method to ± 4 Eotvos units, then the depth at which a minimum mass would have these effects can be found by combining the elementary equations for gravity over a buried spherical mass

$$g = kM/z^2$$

and for the vertical gradient

$$\partial g/\partial z = -2kM/z^3$$

into the form $z = -2g/(\partial g/\partial z)$.

Substituting into this the minimum values for g and $\partial g/\partial z$ gives us $z = 100$ meters. For finding anomalies at greater depths than 100 meters, then, the gradient method is at a disadvantage with respect to straight measurements of gravity.

APPENDIX

Formulas for the vertical component of gravity over a buried spherical mass, and its horizontal derivative, can be found in Nettleton (1940).

The vertical component of gravity, g, is given by

$$g = kMz(x^2 + z^2)^{-3/2}$$

and the horizontal gradient, $\partial g/\partial x$, is given by

$$\partial g/\partial x = -3kMxz\ (x^2 + z^2)^{-5/2}$$

The vertical gradient $\partial g/\partial z$, is found by partial differentiation

$$\partial g/\partial z = kM\ (x^2 - 2z^2)\quad (x^2 + z^2)^{-5/2}$$

where k is the gravitational constant, M the mass, x the horizontal distance to the mass, and z the depth.

REFERENCES

Ackerman, Herman A, and Dix, C. Hewitt, 1955, The first vertical derivative of gravity; Geophysics, v. 20, p. 148-154

Evjen, H. M., 1936, The place of the vertical gradient in gravitational interpretations: Geophysics, v. 1, p. 127-136

Nettleton, L. L., Geophysical Prospecting for Oil, McGraw-Hill, 1940, p. 103-105

Selem, A. M., and Monnett, C. 1953, The application of vertical gradients and comparison of different geophysical methods in a difficult area. Geophysical Prospecting, v. 1, No. 3, p. 308

Thyssen-Bornemisza, Stephen, and Stackler, W. F., Observations of the vertical gradient of gravity in the field: Geophysics, v. 21, p. 771-779

ABNORMAL SEDIMENTARY SUSCEPTIBILITIES IN EASTERN MISSOURI*

THOMAS V. MCEVILLY‡

Editor's Note—This paper won first prize in the SEG Annual Student Essay Award, in 1956.

ABSTRACT

Interpretations of certain magnetic surveys in eastern Missouri, based on the normally valid assumption that sedimentary rocks have zero susceptibility, have demanded extremely high susceptibilities for the granitic basement. As a test of this assumption, susceptibility measurements were made on the sedimentary rocks involved and also on basement samples. Results show the values of basement susceptibility previously used to be many times greater than that observed, and also that several formations possess magnetite concentrations giving them susceptibilities as high as twenty-two percent of that observed for granite, indicating many assumed basement anomalies may be due, at least in part, to sedimentary rocks having high susceptibilities.

INTRODUCTION

Theoretical reduction of observed magnetic data to a definite subsurface structure must meet two major requirements; first, that of a geologically plausible subsurface configuration, and second, that of reasonable susceptibility contrasts in the configuration. Having assumed a configuration and susceptibility contrasts satisfying these requirements, interpretation then consists in refinement of them until the theoretical surface anomaly of the estimated structure and contrasts compares favorably with observed data.

Several magnetic surveys have been conducted in eastern and southeastern Missouri by Saint Louis University graduate students. Interpretations of their data, on the normally valid assumption that the susceptibilities of the sedimentary rocks in the area are zero, have produced some questionable results. In efforts to obtain geologically reasonable results, they have been forced to assume abnormally high susceptibilities for the granitic basement.

Susceptibility measurements by Slichter (1942) on seventy-four samples of granites and allied rocks show that 83% of these have susceptibilities of less than 1000×10^{-6} cgs units and 99% have less than 4000×10^{-6} cgs units.

The abnormal values necessarily assumed in these research problems fall well above the values observed by Slichter. An average value for the basement susceptibilities used in seven magnetic surveys† in this area is approximately 13000×10^{-6} cgs units, which obviously is extremely high.

It is possible that these assumed values are incorrect. If the sediment susceptibilities are not negligible, the basement could then be of more normal susceptibility and the structure might still result in the same observed surface data.

The object of this paper is the first step toward evaluation of this possibility through measurements of the susceptibilities of sedimentary rocks in the area involved.

†Saint Louis University Graduates Theses: Shaefer (1950), Fox (1953), Brerton (1954), Knapp (1954), Orsini (1954), Leaf (1955), and Young (1955).

*B. S. Thesis, St. Louis University, 1956.

‡St. Louis University.

SUSCEPTIBILITY

The magnetic susceptibility of a material is a measure of the extent to which it becomes magnetized when placed in an external magnetic field. Susceptibility may be a positive or negative quantity, depending on whether the material is paramagnetic or diamagnetic, respectively.

If I is the intensity of magnetization or polarization induced in the material when placed in an external field of intensity H, the susceptibility K is defined by the relation

$$K = I/H$$

Since the intensity of magnetization I is defined as magnetic moment per unit volume, then K is the volume susceptibility. If a term $Q = I/d$, specific magnetization, is introduced and defined as magnetic moment per gram, then the mass susceptibility, X, is given by

$$X = Q/H$$

and

$$X = K/d$$

Slichter (1929) found that there are two main factors specifying the susceptibility of a rock, the content of magnetite and the strength of the field in which it lies.

While it is possible that part of the magnetization of the sedimentary rocks under consideration may be remanent this component is neglected for the purposes of this discussion.

SUSCEPTIBILITY MEASUREMENT

A number of methods have been devised and used more or less successfully in susceptibility measurement. Many of these are laboratory methods, requiring special apparatus. However, several techniques for determining susceptibilities of rocks in place have been worked out and are particularly useful.

Among the more common basic methods are:

1. Use of the ordinary field magnetometer in comparing the deflection produced by the unknown to that caused by a standard susceptibility substance of equal volume and shape and similarly positioned, the deflections being proportional to the susceptibilities.
2. Use of the torsion balance in measuring the force exerted on the specimen when placed in a magnetic field of known field intensity (Williams, 1931). If measurements can be made on a specimen of known susceptibility, the characteristics of the field need not be known (Ishiwara, 1920).
3. The inductive methods, exemplified by the susceptibility bridge, in which the output of a transformer having the test specimen as its core is proportional to the susceptibility of the core.

Many other techniques have been devised combining elements from these basic types.

INSTRUMENTATION

Construction

The susceptibility meter used in these investigations is of the inductive type, based on the principle that the energy transfer of a transformer is proportional to the susceptibility of its core. In this case, the core is the specimen to be tested. The measured quantity is the induced secondary current in the transformer.

This instrument is essentially two air core transformers, with secondaries wired in series-opposition. The primary coils are identical, each having 614.5 turns of no. 14 solid enameled copper wire wound on hollow plastic tubes ten inches long and one inch in diameter. The input voltage, or sensitivity control, is regulated by a 3 to 6.5 volt transformer. The secondaries, wound on top of the primaries, are necesarily slightly unbalanced, the test coil having 790.5 turns to 786.5 turns of no. 17 cotton covered solid copper wire on the other coil. This arrangement gives a very small resultant current with no test core inserted. This unbalance results in a sensitivity twice that obtained for balanced coils. It seems that much of the output in the balanced condition is lost in overcoming rectifier resistance.

The output is rectified with a full-wave copper oxide rectifier and measured with a seven-seconds period Leeds and Northrup moving coil galvanometer having a current sensitivity of .0005 microampere per millimeter deflection at one meter.

For the 6.5 volts input used for sedimentary rocks, the field in which the susceptibility determinations were made was computed to be 140 Oersteds at the center of the coil. Obviously such a large field will not give susceptibility values that would be true of the rocks in their natural stage in the earth's field of 0.6 Oersteds. However, relative susceptibilities can be determined and are very useful. Values obtained with this instrument were found to be consistently 10% higher than those measured with a magnetometer as a comparison.

Calibration

Calibration of the susceptibility meter is empirical, based on the linear relationship between susceptibility and percent magnetite in various mixtures of magnetite and pure silica sand. This relationship has been shown to hold for susceptibility measurements with a Ruska vertical magnetometer (Holmes, 1950).

Since crushing the sample to be tested makes it impossible to get the same volume of rock into the specimen tube each time, it is convenient to deal with mass susceptibilities and corresponding deflections per unit mass. Thus the units of calibration are those of mass susceptibility, X. Volume susceptibility, K, can easily be determined by multiplying X by the density of the rock. The procedure of calibration consists of plotting a graph of deflection per unit

mass versus percent magnetite for the various mixtures. Because of the high sensitivity used for the sedimentary rocks, mixtures from 0.05 to 0.5 percent magnetite gave a susceptibility range large enough to cover all the samples. The resulting graph is a straight line through the origin. Thus, fixing one point of known susceptibility on the line will convert the abscissae into units of susceptibility.

The fixed point on the line was obtained by testing a specimen of pure ferric chloride, which has a mass susceptibility of 90×10^{-6} cgs units.*- This sample gave a deflection equivalent to that of a 0.101% magnetite mixture. On this information, the magnetite percentages were converted directly into units of mass susceptibility.

Figure 1 is the resulting calibration curve, with which the deflection per unit mass of the rock sample is related to its mass susceptibility.

A slight variation of the curve from linearity at high magnetite percentages seems to be a characteristic of the instrument, possibly due to change in rectfier resistance with larger currents.

With this method of calibration it is estimated that the resulting susceptibility value may be in error of 15%. As a check, three arbitrary rock samples (not used in this work) were tested with the susceptibility meter and then with the Ruska vertical magnetometer. It was found that the susceptibility meter value was consistently higher than that of the magnetometer, with an average difference of 10% and a maximum of 14%.

MEASUREMENTS

From an inspection of the geologic sections in areas of the magnetic surveys which gave rise to this study, it was seen that any sediments of abnormal susceptibility affecting these surveys probably do not lie above the St. Peter sandstone of Ordivician Age ("Wilcox" in Oklahoma). On this basis, it was decided to make susceptibility measurements of the approximately 1500 feet of sediments from the St. Peter to the basement. A simplified columnar section of the twelve formations involved is given in Figure 2 (Weller and St. Clair, 1928). Samples of granite and a very basic intrusion were also included in the measurements as means of comparison.

The choice of outcrops from which samples were taken was one of convenience. In Ste. Genevieve County, Missouri, State Highway 38 runs perpendicular to the strike of the beds dipping to the northeast, away from the Ozark uplift. Along this highway, in a distance of approximately ten miles, nine of the twelve beds, and the basement, outcrop. About five miles north the remaining three can be found in a distance of one mile. Figure 3 is a map of Ste. Genevieve County, showing the locations where the various samples were obtained.

*-Smithsonian Physical Tables, 8th Edition, 1933.

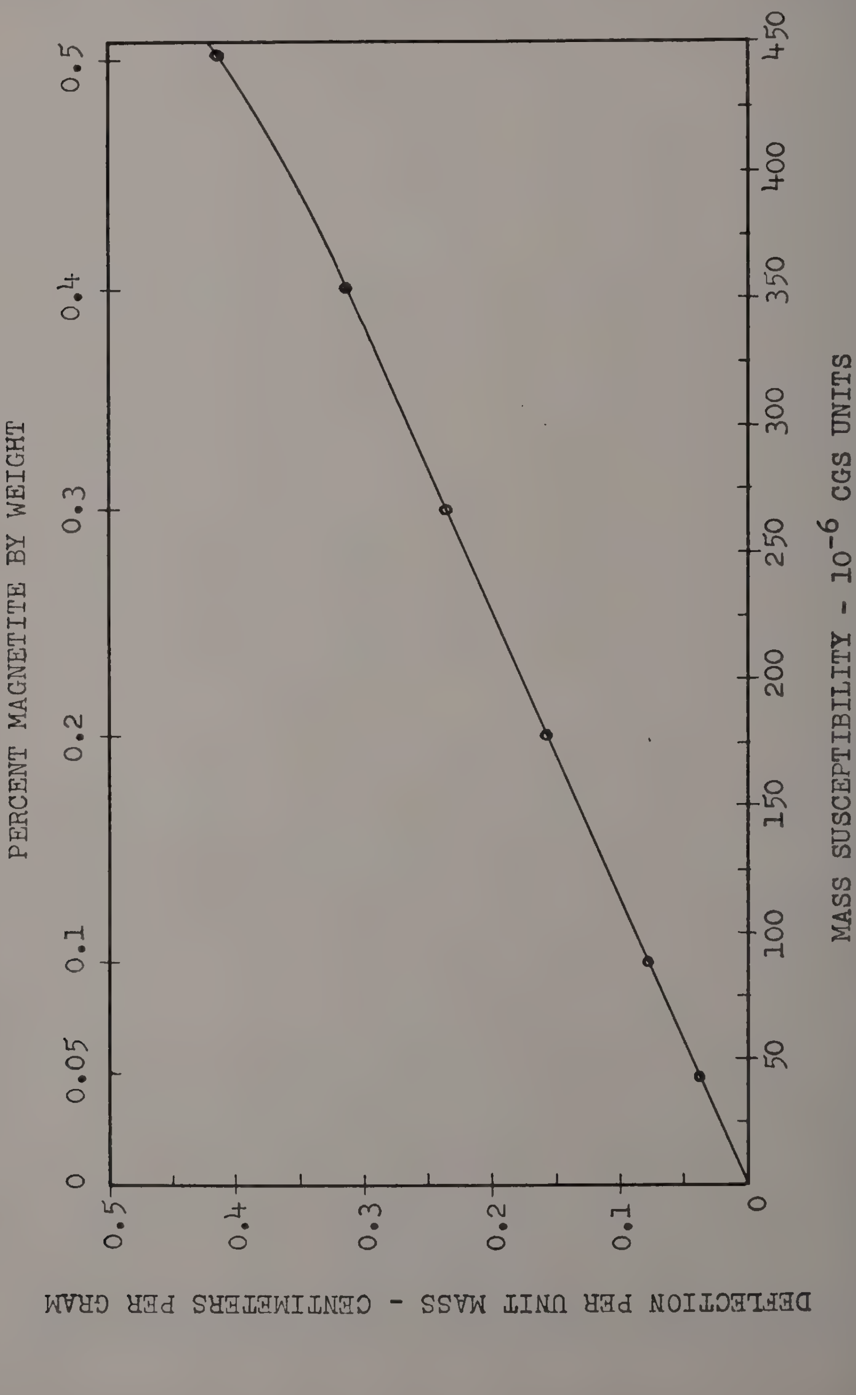


FIGURE 1. Calibration curve for susceptibility meter.

System	Series	Formation	Section	Thickness (feet)	Rock Character
ORDOVICIAN		St. Peter		75-90	Sandstone, white, pure.
		Everton		55-85	Sandstone, white.
	Canadian	Powell		170-200	Dolomite, cherty at top, sandy at base.
		Cotter		60-80	Dolomite, oolitic, thin chert beds
		Jefferson City		140-180	Sandstone, dolomite, and chert.
		Roubidoux		50-70	Sandstone, dolomite, and chert.
	Ozarkian	Gasconade		250-300	Dolomite, light colored, crystalline, with sand lenses, sandstone at base.
		Potosi		160-180	Dolomite, chocolate colored, crystalline.
CAMBRIAN	Upper	Derby-Doerun		8-70	Dolomite, hard, dense, fine-grained.
		Davis		65-80	Dolomite, irregular shale beds.
		Bonneterre		40-390	Dolomite, fine to medium grained, irregular shale and limestone beds, sandy at base.
		Lamotte		110-220	Sandstone, fine to coarse grained, yellow to white, coarse arkosic conglomerate at base.
PRE-CAMBRIAN	Laurentian	Rhyolite and Granite, cut by Acid and Basic Dikes			Red coarsely crystalline granite, dark colored rhyolite porphyry, granite and dark diabasic or greenstone dikes.

FIGURE 2. Simplified columnar section of the lithology studied.

In taking specimens from the exposed rock, a sledge was used to break away all the weathered surface rock until an apparently fresh piece could be obtained.

Originally the specimens were crushed by hand with a steel block and plate. Some extremely high susceptibilities were found and, upon microscopic examination, the samples showed considerable steel contaminations from the crushing.

New specimens were then ground to ten mesh in an agate mortar to avoid contamination.

The actual susceptibility measurement of a sample involved packing the crushed rock into the specimen tube and then weighing the tube and rock to get the weight of the rock. The tube was inserted into the test coil and the deflection of the reflected light spot was noted.

The observed deflection was divided by the weight in grams and the mass susceptibility could be read directly off the calibration curve.

Table 1 presents the results of these measurements, giving the deflection per gram, both mass and volume susceptibility, and their percentage of the measured granite susceptibility, for each formation.

A lower sensitivity calibration curve was made to obtain an approximate susceptibility of the basic intrusion.

It is seen that only three formations have susceptibilities worth further consideration; the Cotter Dolomite, the Roubidoux Sandstone and Dolomite, and the Potosi Dolomite.

To determine the cause of these rather high values, an electromagnet was used to separate any possible ferromagnetic substances from the crushed rock samples. An appreciable amount of material was separated from each of the three specimens. These particles were then studied microscopically. It was found that all three rocks contained sizeable amounts of fine granular magnetite and that the Cotter Dolomite also contained a considerable amount of pyrite. The magnetite content seemed sufficient to explain the abnormal susceptibilities which corresponded to a maximum of .07% in the calibration mixtures.

As a check, the specimens were again tested with the susceptibility meter after having removed all magnetic material with the electromagnet. The resulting deflections were negligible.

CONCLUSIONS

From the values of susceptibilities determined in this work, it appears that the assumed susceptibility value of 13000×10^{-6} units for the Pre-Cambrian basement in eastern and southeastern Missouri is extradordinarily large. * This value is over fifteen times the observed granite susceptibility and over five

*Note—Magnetic anomalies of the order of magnitude and areal extent discussed by the author have also been observed in southeastern Kansas by the editor.

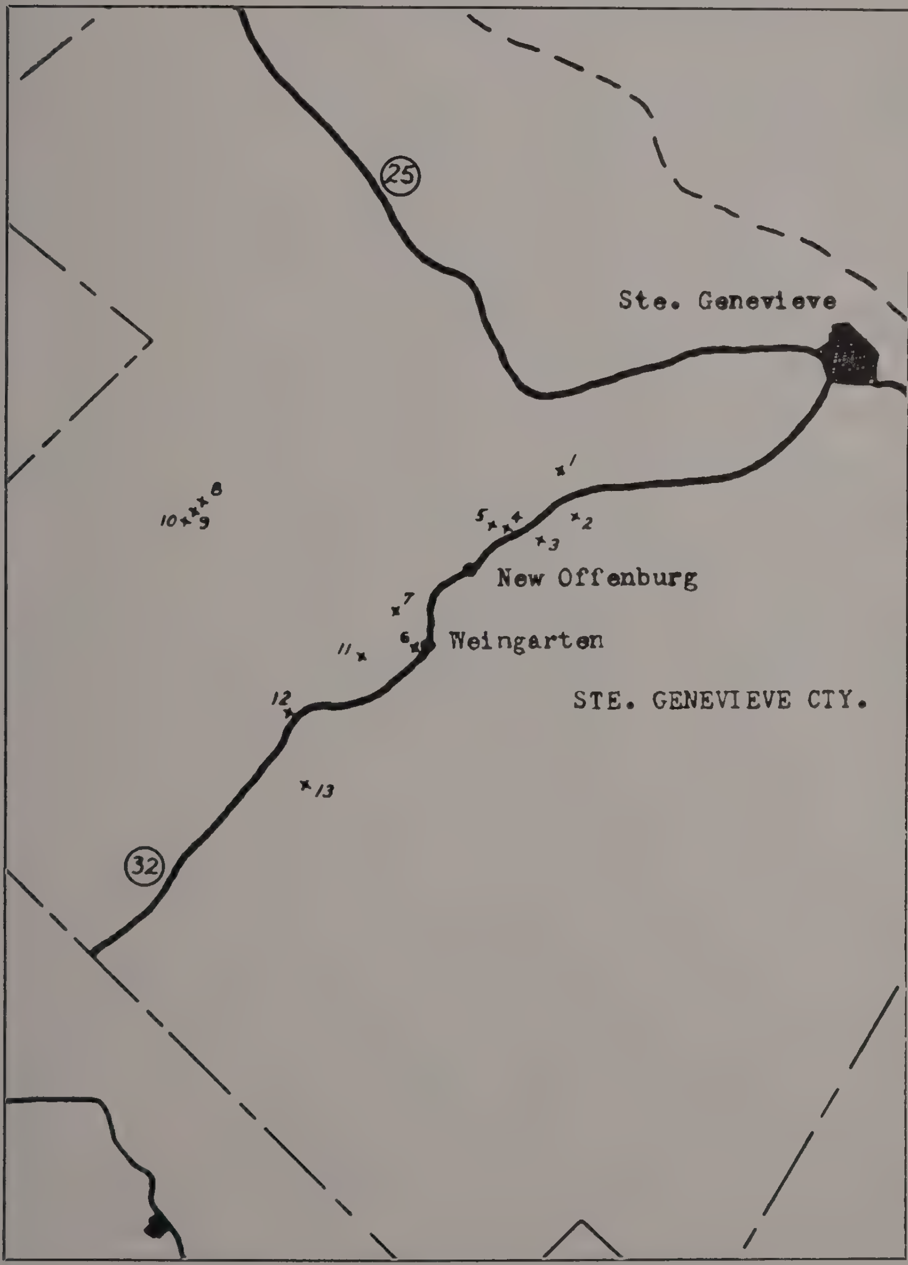


FIGURE 3. Ste. Genevieve County, Mo., and outcrop locations.

Formation	Deflection cm/gm	Mass Susceptibility, (X) 10^{-6} cgs units	Percent of Mass Susceptibility of Granite	Approximate Density gm/cc	Volume Susceptibility, (K) 10^{-6} cgs units	Percent of Volume Susceptibility of Granite
St. Peter	0	—	—	1.8	—	—
Everton	0	—	—	1.8	—	—
Powell	.00337	3.8	1.2	2.5	9.5	1.2
Cotter	.0295	33.0	11.6	2.5	82.5	10.9
Jefferson City	.00453	5.1	1.8	2.5	12.8	1.7
Roubidoux	.0427	47.8	16.7	2.4	117	15.4
Gasconade	.00348	3.9	1.5	2.5	9.9	1.3
Potosi	.0556	62.2	21.8	2.5	158	20.8
Derby-Doerun	.00551	6.2	2.2	2.5	15.7	2.1
Davis	.0128	14.3	5.2	2.2	32.4	4.3
Bonneterre	0	—	—	2.5	—	—
Lamotte	0	—	—	1.8	—	—
Granite	.255	285	100	2.7	760	100
Basic Intrusion	Special Calibration	800	281	3.0	2400	316

TABLE 1. RESULTS OF SUSCEPTIBILITY MEASUREMENTS

times that measured for a very basic intrusion.

Three of the twelve tested formations had a susceptibility greater than a tenth of that of the granite. One of the three gave a value over a fifth that of the granite. For sedimentary rocks, these are abnormal susceptibilities.

Analysis of these three rocks showed significent concentrations of magnetite. Such concentrations and susceptibilities probably vary greatly throughout any one formation.

The observed high susceptibilities, even if fairly near the surface, do not alone seem to be enough to explain the anomalies encountered. Some basic studies of the anomalies by continuation has indicated deeper sources.

However, it is possible that a combination of a basement irregularity and the effects of arched sediments of high susceptibilities could produce an anomaly of the observed type. In less detailed continuation study this anomaly may appear to be totally from a deep source.

It is also possible that the observed anomalies are due to areas of very high magnetite concentrations in the sedimentary rocks or in the basement caused by local conditions favorable to its presence.

In view of the appreciable susceptibilities and magnetite concentrations found in several formations, and also of the extreme discrepancy between previously assumed basement susceptibilities and those measured in these studies, it seems that much more intensive consideration should be given to the possibility that large anomalies observed in eastern and southeastern Missouri may be due, at least in part, to the occurrence of sedimentary rocks having appreciable susceptibility in the areas involved.

REFERENCES

Holmes, C. R., 1950, Magnetic Fields Associated with Igneous Pipes in the Central Ozarks: M. S. Thesis, St. Louis University.

Ishiwara, 1920, Science Reports, Tohoku Imperial University, v. 9, p. 236.

Slichter, L. B., 1929, Certain Aspects of Magnetic Surveying: AIME Geophysical Volume, p. 238.

Slichter, L. B., 1942, Magnetic Properties of Rocks: GSA Special Paper, No. 36, p. 293.

Weller, S. and St. Clair, S., 1928 Geology of Ste. Genevieve County, Missouri; Missouri Bureau of Geology and Mines, Second Series, v. 22.

Williams, S. R., 1931, Magnetic Phenomena: New York, McGraw-Hill.

EDITORIAL COMMENT — AT THE CROSSROADS

We are at the crossroads. Since its inception, the PROCEEDINGS has been beset by a multiplicity of divergent editorial policies. This stems from the fact that the By-Laws, Article IV, directs the Editor to "be sole judge" of what is to be published. He, therefore, determines what his particular editorial policy shall be. Each editor in turn has published his respective issue with the hope and feeling that the contents would be of benefit and serve as a reference volume for the membership at large.

This lack of a stable and continuous editorial policy has created diverse comment and some criticism. It has even been suggested by some of the *profanum vulgus* that the Society discontinue the publication. Thus, the PROCEEDINGS continues to suffer from growing pains.

It is not without hope that the present editor feels that in the future, this lack of a set and stable editorial policy will be corrected. In this connection it is felt that two suggestions are in order.

First, it is suggested that the incoming Council take up the matter of editorial policy with the membership at large in open meeting, to determine just what the majority of the members wish in the way of a publication of this kind. Should a continuous theme be followed in the future, or, should we proceed as in the past with each succeeding editor adopting his own particular *litterae scriptae* for his respective issue? Would the majority of the members prefer an issue containing several short but original papers which are of current and perhaps controversial interest, along with a paper or two of a local nature, or would the PROCEEDINGS best serve our membership by containing subject matter of a statistical character which could be filed as reference material? These and perhaps other questions should be settled so that we will have a stable publication.

It is the opinion of some that to publish original papers of merit would place the PROCEEDINGS in direct competition with GEOPHYSICS. This, of course, we do not want to do. However, it is felt by others that there is need for a publication in which original material that is either too short or too local in its nature to be placed in GEOPHYSICS, but which otherwise is not inferior to papers found in that publication, can appear.

Second, it is suggested that like SEG, the Society elect the future editors for a two year tenure of the editorship. The experience and knowledge gained by those of us on a first publication of this character is quite valuable, and the Society would benefit greatly with a second issue by the same editor.

Two volumes have now been published containing valuable statistical material, and two which featured short articles on various phases of geophysics. Perhaps there are other ideas which would better serve the needs of the membership.

Whatever the future may hold for the PROCEEDINGS, it is hoped that, like the Society itself, it will mature, and become one of the recognized technical publications of the profession.

We are at the crossroads. Now is the time to decide to which road the editorial policy of the PROCEEDINGS shall be committed.

V. L. JONES

ABSTRACTS OF PAPERS AND LECTURES GIVEN BEFORE THE GEOPHYSICAL SOCIETY OF TULSA 1955-56

THE COMPOSITION OF REFLECTIONS

by

J. P. Woods
Atlantic Refining Company
October 13

When the traces on a seismic reflection record all show about the same deflection at about the same time, the line-up is marked and called a seismic reflection. An important fact is forgotten. The fact is that the reflection seen on the record is nearly always a composite of the various reflections caused by a set of closely spaced reflecting layers. When the arrangement of the layers in the set changes, then the various reflections add together in a different way, and the character of the composite reflection seen on the record changes.

A series of artificial seismic records have been made to show this composition of reflections. The records were made by connecting a standard reflection seismograph to an acoustic model. The model was a three hundred foot length of steel pipe with input and output transducers at one end. Records were made for a wedge, a pinch-out, a complex of thin layers, a sand bar, layers corresponding to well resistivity logs, and a regular layer system.

APPLICATIONS OF VELOCITY LOGGING TO EXPLORATION PROBLEMS

by

Alan A. Stripling
Magnolia Petroleum Company
November 10

Acoustic velocity logs have been made of wells located in widely separated areas with various lithologies. These logs have been useful in identifying reflections on seismograms, in determining vertical travel times, and in correlating strata from well to well.

Recent theoretical studies of elastic wave velocities for ordered packings of quartz spheres have led to the conclusion that the speed of sound through these packings will be appreciably lower when they are saturated with oil or gas than when saturated with water only. Continuous velocity logs of sand formations containing oil or gas have confirmed this theoretical conclusion. The depression of velocity is particularly marked in sands of high porosity where velocities measured in oil and gas sands have been 20 percent lower than

velocities in salt water sands of the same porosity. This change in velocity may be attributed to the difference in compressibility between hydrocarbons and water.

Another factor affecting the acoustic velocity of a formation is its porosity. Velocity increases with decreasing porosity.

The velocity log thus provides supplementary information of value in locating oil and gas bearing reservoir beds and in differentiating between these and low porosity beds of similar lithology.

GEOPHYSICAL CASE HISTORY OF THE PARENTIS OIL FIELD, FRANCE

by

George G. Walton

Carter Oil Company

December 8

In 1951, the French Government granted an exclusive exploration permit to the Esso R.E.P. (a Standard Oil Company affiliate) over an area of 4,357,980 acres around Bordeaux in the northern part of the Aquitaine Basin. This area was investigated first by surface geology, then it was surveyed by the gravity meter. In checking the gravity anomalies by the reflection seismograph, a subsurface structure was found at Parentis in 1953, which was drilled in 1954, and was proved to be oil bearing. The Parentis oil field is the most important oil field, not only in France, but in all Europe outside the Iron Curtain.

Gravity map, seismograph map, seismic profiles, telluric map and geological contour maps, and cross sections of the Parentis structure were presented.

PROSPECTING FOR GROUND WATER BY INDUCED ELECTRICAL POLARIZATION

by

Victor Vacquier

S.E.G. Distinguished Lecturer

New Mexico Institute of Mining and Technology

January 11

When a direct current between two grounded electrodes is interrupted, a potential difference between another pair of electrodes is observed by decay for about one minute or more if a substantial portion of the current path consists of freshwater aquifer. The magnitude of this residual polarization voltage is only a few per cent of the voltage that appears between the potential electrodes during passage of the current. Laboratory experiments on known

clay-sand mixtures prove that the polarization effect depends on cation exchange in the clay minerals dispersed in water-saturated alluvium or sandstone. Clay content, ion content of the water, and the grain size of the matrix have to be considered in the interpretation of field data. Induced polarization increases with resistivity. Its relaxation time also increases with the grain size and therefore with the permeability of the matrix. This latter property was checked at a well field south of Alamogordo, Mexico. With 10 kw of power thick water bearing formations have been detected down to 400-foot depths. Simple characteristic field conditions have been studied in a model tank.

ITALY, FUTURE OIL PROVINCE OF EUROPE

by

Carl Savit

Western Geophysical Company

February 9

Carl Savit discussed the present status of the petroleum industry in Italy and its future prospects.

DISPLAY OF MAGNETICALLY RECORDED SEISMIC DATA

by

C. F. Hadley

Pan American Petroleum Corporation

March 22

A method of making multitrace seismic records using electrically sensitive paper is described. The record is immediately available for use without any type of processing. A rotating scanning disk carrying wire brushes on its periphery is revolved with its axis parallel to the direction of the motion of the paper. The electrical paper is pulled under the scanning disk. The paper is so shaped that brushes remain in contact with the paper. Short electrical pulses are fed to the brushes so as to produce a number of traces composed of closely spaced dots. The position of the dots is determined by the time of occurrence of the pulses which is a function of the amplitude of the seismic signal. Timing lines are placed on the record by feeding a series of dots to all brushes in unison. Provision is made to count down and emphasize the fifth and tenth timing lines. A system of multiplexing is used to employ each brush on many traces and thus reduce the rotational speed of the scanning disk. The frequency response is satisfactory for seismic work.

THE GEOLOGIC CAUSES OF GRAVITY ANOMALIES

by

Robert J. Watson

The Carter Oil Company

April 12

The appearance on gravity maps of various kinds of anomalies to be ex-

pected in a basin area was demonstrated by means of synthetic examples. Conditions of density contrast and structural relief necessary to produce detectable anomalies were shown. The possibilities of these favorable conditions being present in the Mid-Continent area were briefly considered.

GEOLOGIC INTERPRETATION OF AERO-MAGNETIC SURVEYS

James Affleck
Gulf Research and Development Company

May 7

(Meeting held jointly with Tulsa Geological Society)

Introduction

The purpose of this address is to develop the geological significance of magnetic anomalies and to demonstrate the part which magnetics can play in an integrated geological and geophysical exploration program.

The sedimentary rocks are usually so nearly non-magnetic that they contribute little or nothing to the magnetic anomalies. Therefore, the magnetic method deals with the igneous and sometimes the metamorphic rocks. Magnetics must therefore be considered a reconnaissance method, and its utility is limited to the degree that knowledge of the depth and configuration of the igneous rocks can contribute to knowledge of the overlying sedimentary section. Magnetic anomalies are of two types, those associated with basement uplift and those caused by changes of rock magnetization within the basement. The problem of the interpreter is to attempt to select between the two types. Usually the anomalies due to intra-basement contrasts are stronger than those due to basement relief.

The Gulf airborne magnetometer, survey procedures and data reduction processes were described briefly. The fundamentals of interpretation techniques were demonstrated. These included demonstrations of anomaly types, derivative techniques, and basement depth calculations.

Utilization of Results

The role of magnetics in an integrated exploration program was described. Through basement depth calculations, it is almost always possible to answer the following questions:

1. Is there a sedimentary basin within the area?
2. If so, what is its configuration?
3. Can any portions of the area be eliminated from further consideration?

Examples of magnetic surveys and assemblies of magnetic anomalies were used to demonstrate this part of the problem. Generalized magnetic profiles were shown. These included a profile across the Delaware Basin, Central Basin Platform, Midland Basin, Eastern Platform, and the Llano Uplift; a profile across the Wichita Mountains and the Anadarko Basin; and a profile across the Arbuckle Mountains and the McAlester Basin. The basin areas were defined by magnetics, as were the asymmetrical axes, the mobile, and the stable belts within the basins.

The selection of dominant magnetic trend patterns was demonstrated, and the relationships of these trends to basement zones of weakness was emphasized. Rejuvenation of these zones of weakness during deposition may have formed structures.

Selection of basement relief by means of the derivative technique was demonstrated. Examples used were in Wilbarger County, Texas, on the Red River Uplift, in the Sayre area of Oklahoma, and in Crane County, Texas. In areas of fairly uniform basement or in which igneous activity has taken place after sedimentary deposition, the method works well. In areas of complex basement with numerous magnetization contrasts, the difficulties of separation are great.

Comparisons between magnetic and gravity surveys can yield results not obtainable from either one alone. An example was shown in which the magnetics showed an area of shallow basement and an area of deep basement, the latter with little evidence of local structure. Strong, shallow-source gravity anomalies were present in both parts. In the area of deep basement, the gravity anomalies certainly represent sedimentary structure, while in the area of shallow basement they are associated with density contrasts within the basement.

Two examples of magnetic data along the California coast were shown. One showed the relationship to the San Andreas Fault and the other suggests the offshore position of that fault. Another slide showed the existence of an anomaly in association with the Medocino Escarpment.

Comparative costs of magnetics, gravity, and detailed seismograph were given as 1:3:100.

ABSTRACTS OF PAPERS AND LECTURES GIVEN BEFORE THE GEOPHYSICAL SOCIETY OF TULSA

1956-57

GEOLOGY AND GEOPHYSICS OF THE GULF OF MEXICO

by

Paul L. Lyons
Sinclair Oil and Gas Company

October 11

The combined geology and geophysics of the Gulf of Mexico make this vast basin area an anomaly unique on the crust of the earth. The Gulf is a great gravity maximum and is relatively featureless in its magnetic picture.

The conclusion is warranted that the Central Gulf itself is an undisturbed portion of the earth's crust destined to sink further and to receive many thousands of feet of sediments which will be deposited in discreet limited basins encroaching from the shore of the North American continent.

Moot questions are: The amount of sediments in the Gulf and the extent of the Jurassic (?) salt.

THE IMPORTANCE OF STRUCTURAL INTERPRETATION OF SEISMIC DATA

by
R. A. Weingartner
Pan American Petroleum Corporation
October 11

At a time when complicated structural concepts appear to be the rule rather than the exception, too little effort is being spent on the study of stratigraphic and structural possibilities offered by the seismic cross section data, and too little effort is spent by the geologist in making use of the data. Steps to increase the effort envisage (1), development of qualified personnel for structural and stratigraphic interpretation with responsibilities limited to the cross section and map making; (2), construction of seismic cross sections and display of seismic map data in the most useable form for all geologists; (3), a program to encourage the use of seismic file data and the insistence by the geophysicist that the geologist make use of the data on a constant and routine basis.

Illustrations are provided to show the inadequacy of our present effort and the need for cross sections and seismic maps on a scale and in terms understandable by geological personnel of limited experience.

INVESTIGATION OF SHEAR WAVES

by
R. N. Jolly
The Carter Oil Company
November 8

Measurements made to investigate some of the properties of shear waves were discussed. Recordings were made of direct, refracted, reflected, and surface waves generated by the horizontal recoil of a gun-like device. Special emphasis was placed on determining fundamental properties of SH-type shear waves and their applicability to reflection prospecting.

AUTOMATIC METHODS OF COMPUTING WAVE FRONTS AND RAY PATHS OF THE PROPAGATION OF SEISMIC ENERGY

by
W. O. Heap
Seismograph Service Corporation
November 8

It has long been recognized that, in general, seismic velocities vary principally due to changes of lithology, age, and depth of burial. This variation in velocity is usually expressed in terms of reflection time or in terms of depth.

When the subsurface formations are dipping more than a few degrees it is necessary to compute the true depth and displacement of the depth points. The combination of variable velocity and dip introduce mathematical relationships which are tedious to solve by ordinary means.

This paper introduces automatic computation procedures utilizing an electronic calculator which may be programmed to solve the necessary computations involving any velocity function for the construction of (1), Wave Front Charts, (2), Plotting arm scales, or (3), Tables for table-look-up operations.

Special treatment is given the linear increase of velocity with depth and the linear increase of velocity with time.

An interesting and useful application is described in detail involving (1), A variable initial velocity with a linear increase of velocity with depth and (2), The use of two different velocity functions, the lower function representing an interval velocity in which the upper horizon varies in depth sufficiently to cause the velocity at its surface to vary over a wide range thus directly affecting the initial velocity of the lower function. Only one wave front chart is constructed and two supplementary charts are used for adjusting the wave front chart for use with any initial velocity.

RECOGNITION OF THE EFFECTS OF DIFFRACTION IN EXPLORATION SEISMOLOGY

by

John Bemrose
Sohio Petroleum Corporation

December 13

Reflection and diffraction of longitudinal waves were illustrated by slides and a slow motion film of wave motion in a shadow tank and a means of recognizing diffraction events on a seismogram by their migrational and other properties was demonstrated.

EXPERIMENTS WITH A TWO-DIMENSIONAL SEISMIC MODEL

by

W. T. Born
Geophysical Research Corporation

December 13

A two-dimensional Seismic Model has been used to study diffraction phenomena of two types; those associated with subsurface discontinuities and those associated with surface irregularities. Model records were shown to display diffraction at a fault zone and also to illustrate the effect of surface irregularities upon seismic record quality. An attempt was made to relate the results of model-studies to practical field work.

GEOPHYSICAL CASE HISTORY
BIG MINERAL FIELD, GRAYSON COUNTY, TEXAS

by

C. A. WOOD
Shell Oil Company

January 10

The Big Mineral Field is situated on an arm of Lake Texoma in Grayson County, Texas. Geologically it is in the Marietta Syncline. The Shell Oil Company started seismic exploration in the Big Mineral Area in 1947. The early seismic maps were not very attractive because of the lack of control on the east flank of the prospect, which was under the lake. An abandoned test about one mile southwest of the present field was another discouraging factor before the prospect was tested. After the discovery well was drilled, additional seismic control was obtained on the eastern flank on the structure. As finally mapped, the structure consists of a faulted anticline.

Slides were presented showing seismic maps, a seismic profile, sample records, a subsurface map and a subsurface profile.

DATA PROCESSING SYMPOSIUM

February 14

I. Brief History—W. B. Robinson
Gulf Oil Corporation, Oklahoma City
   - A. Basic concepts on obtaining data
      1. Conventional records
      2. F. Rieber developments
      3. Magnetic tape recording
         Type of modulation, etc.

II. Manipulation of Data – Kenneth E. Burg
Geophysical Service, Inc., Dallas
   - A. Static and dynamic corrections
   - B. Cross and auto correlation
   - C. Filtering (linear, time domain, forward and reverse playback, etc.)
   - D. Compositing or stacking
   - E. Sequential playback

III. Presentation of Data – R. A. Peterson
United Geophysical Company, Pasadena
   - A. Record sections – time
   - B. Record sections – time versus depth
   - C. Optical representation
      1. Conventional
      2. Variable density

3. Variable area

D. Direct viewing of traces

E. Non-photographic recording

IV. Interpretation — N. B. Widess
Pan American Petroleum Corp., Tulsa

A. How have the various data processing methods affected interpretation?

1. Advantages

2. Disadvantages, etc.

V. Slides to show examples

A. Gulf Oil Corporation

B. Continental Oil Company

C. Geophysical Service, Inc.

D. United Geophysical Company

E. Seismograph Service Corporation

F. Century Geophysical Corporation

G. Sinclair Oil and Gas Company

VI. Audience discussion addressed to panel

SIGNAL TO NOISE RATIO IMPROVEMENTS BY CORRECTING FOR NORMAL STEP-OUT, AND FOR VARIATIONS DUE TO WEATHERING AND ELEVATIONS

W. E. Richardson
Continental Oil Company

March 7

This paper was concerned with the effect of trace corrections when used with phase discrimination for improving signal-to-noise ratios on seismogram records. It is a qualitative treatment showing how actual field records were improved by applying static corrections to compensate for variations due to weathering and elevation, and dynamic corrections to remove normal step-out.

NOTES ON REFINEMENTS IN REFRACTION TECHNIQUE, AND ADAPTATION TO NEAR SURFACE CORRECTIONS

by
H. L. Mendenhall
Phillips Petroleum Company

April 11

Conditions exist in the near-surface rocks in many of the areas explored by the reflection seismograph that profoundly influence the travel times of the

deeper reflections. These conditions exist at depths considerably below the depths of present day economic drilling and quite often a measure of these effects is a prerequisite to the correct correlations. The salt problem of the Western Anadarko Basin is an example of this problem and several other areas are postulated as examples. Refinements in the reversed inline refraction profiling technique were described which can be employed to solve these problems.

GETTING THE MOST OUT OF PRESENT SEISMIC INSTRUMENTS

by
J. E. Hawkins
Seismograph Service Corporation

May 9

Much of the present seismic work is being carried out in areas where results are difficult to obtain. The paper outlined the requirements for seismic instruments for these operations. The particular characteristics desired for specific problems were illustrated, and the instrument factors that affect these characteristics were outlined. Examples of the effect of instrument adjustment were shown. Means of arriving at optimum results with present equipment under diversified field conditions in different areas were illustrated by specific cases. The application of recent instrument developments as an aid to interpretation was discussed.

CONSTITUTION AND BY-LAWS

(*As amended to November* 13, 1952)

ARTICLE I

The name of this Society is the *Geophysical Society of Tulsa*. It shall be the Tulsa Section of the Society of Exploration Geophysicists.

ARTICLE II

OBJECT

The object of this Society is to promote the science of geophysics especially as it applies to exploration, and to promote fellowship and cooperation among those persons interested in geophysical problems.

ARTICLE III

MEMBERSHIP

1. Any person interested in the geophysical profession shall be eligible for membership.
2. Applications for membership shall be submitted in writing, and shall be signed by three sponsors who are members of the Society.
3. Applications shall be approved for membership by the Executive Committee.
4. The annual dues of members of the Society shall be three dollars ($3.00) payable in advance on the first day of each calendar year.
5. Members whose applications are approved after July 1 shall be required to pay only one-half the regular annual dues for the remainder of the first year of their membership.
6. Charter Members of this Society will be those who attended the first organizational meeting of the Society on February 4, 1947, or who attended the second meeting on March 13, 1947, and signed the respective roll as charter members, and who have paid dues for the year 1947.

ARTICLE IV

RESIGNATION AND SUSPENSION

1. Any member may resign from the Society at any time. Such Resignation shall be in writing and shall be accepted by the Executive Committee, subject to the payment of all outstanding dues and obligations of the resigning member.

Note: The Constitution was originally adopted March 13, 1947. It was amended January 8, 1948, November 11, 1948, February 9, 1950, and November 13, 1952. The By-Laws were amended February 9, 1950, and November 13, 1952.

2. Any member who is more than one year delinquent in payment of dues shall be suspended from the Society. Any delinquent or suspended member, at his own option, may request in writing that he be dropped from the Society and such request shall be granted by the Executive Committee after due notification. Any member more than two years in arrears shall be dropped from the Society.

3. Any person who has ceased to be a member under Section 1 or Section 2 of the Article may be reinstated by unanimous vote of the Executive Committee subject to the payment of any outstanding dues and obligations which were incurred prior to the date when he ceased to be a member of the Society.

ARTICLE V

OFFICERS AND THEIR DUTIES

1. The officers of the Society shall be: President, First Vice-President, Second Vice-President, Secretary, Treasurer, and Editor.

2. There shall be district representatives to the Society of Exploration Geophysicists, as provided in the constitution of that society.

3. The Executive Committee shall consist of the Officers, the two most recent available past presidents, and the district representative, or representatives, to the Society of Exploration Geophysicists.

4. The Officers shall be elected by a ballot as hereinafter provided at the Annual Meetings, and shall hold office for one year.

5. The President shall preside at the meetings of the Society and of the Executive Committee. He shall call special meetings when deemed advisable; shall appoint all committees except as otherwise herein provided; and, jointly with the Secretary-Treasurer, shall sign all written contracts and other obligations of the Society. In the temporary absence of other Officers, he shall assume their duties or delegate them.

6. The First Vice-President shall be responsible for arranging the technical program of the Society, and shall have authority to appoint such assistants as he may require. He shall perform the duties of President in the absence or disability of that Officer, and in case of the President's resignation shall become President for the remainder of the term.

7. The Second Vice-President shall be responsible for arranging entertainment, and shall have power to appoint members to assist him.

8. The Secretary shall maintain a complete list of the membership of the Society and of its Executive Committee, shall mail advance notice of meetings to all members, shall keep minutes of meetings of the Society, and of its Executive Committee, shall notify the members by mail of proposed amendments to the Constitution, and shall mail and receive ballots.

The Secretary shall submit to the Secretary-Treasurer of the Society of Exploration Geophysicists a report of each meeting of this Society and of its Executive Committee within two weeks following each such meeting. He shall also submit to the Secretary-Treasurer of the Society of Exploration Geophysicists the names of all Officers and Committee members within two weeks after their election or appointment.

9. The Treasurer shall collect all dues and other obligations to the Society, shall make disbursements authorized by the Executive Committee and shall transact such other business as may be authorized by the Executive Committee. He shall maintain a chonological record of all receipts and expenditures as well as a system of records explaining each expenditure, including evidence of authority to expend funds and evidence of payment. He shall report the condition of the Treasury at each Annual Meeting and at other times upon request of the Executive Committee.

   When so instructed by the Executive Committee, he shall make application to the Secretary-Treasurer of the Society of Exploration Geophysicists for such portion of the expenses to be borne by that Society, as may be needed, and shall submit to the Secretary-Treasurer of the Society of Exploration Geophysicists, prior to the annual meeting of that Society, an itemized account of the expenditure of such funds as may have been received from the Society of Exploration Geophysicists during the preceding calendar year.

   A quorum of the Executive Committee shall consist of at least four members and approval by at least four members will be necessary to conduct all business of the Society.

10. The Editor shall be in charge of the editorial business, shall submit an annual report of such business, shall have authority to solicit papers and material for the regular society publication and for special publications, and may accept or reject material offered for publication. He may appoint editorial assistants.

11. The Executive Committee shall transact all business of the Society not otherwise herein specifically provided for. It shall elect all members to the Society, shall authorize all expenditures, shall direct investments of Society funds, shall establish and supervise publications; shall approve and recommend all proposals for special assessments; shall fill vacancies occuring in any office except in the office of President, to which the First Vice-President automatically succeeds, and shall have the power to review all actions and appointments by the Officers.

12. The District Representatives of the Society of Exploration Geophysicists shall represent the Society and its members at meetings of the Council of the Society of Exploration Geophysicists.

ARTICLE VI
ELECTION OF OFFICERS

1. A slate of nominations for officers shall be prepared by a Committee

of Nominations consisting of the President and the two most recent available Past Presidents. They must secure the consent of all candidates nominated. This slate, of two or more candidates for each office, shall be prepared and announced to the Society at its regular meeting in March of each year.

Additional nominations for each office may be made by written petition of ten or more members in good standing. Such nominations must be submitted to the President not later than the close of the regular meeting in April.

The election of officers shall be by secret mail ballot. The Secretary shall mail to all members, not later than three weeks preceding the Annual Meeting, a ballot listing all candidates properly nominated for each office. Each member voting shall cast one vote for each officer and shall return his ballot to the Secretary in a sealed envelope carrying on the outside his written signature. Only ballots so prepared by members in good standing and received by the secretary by 4 P.M. on the Monday immediately preceding the Annual Meeting shall be valid.

The Secretary shall indicate which ballots are valid and shall deliver them unopened to the Committee on Nominations. The Committee on Nominations shall supervise the counting of ballots prior to the Annual Meeting. The candidates receiving the greatest number of votes cast for an office shall be declared elected to that office. In case of a tie, the Executive Committee shall decide which of the tied candidates shall be elected.

2. The Committee on Nominations shall prepare a slate of nominations for any posts of district representatives to the Society of Exploration Geophysicists, which may need to be filled. Additional nominations may be made in the manner set forth in Section 1. The election shall be by secret ballot at least three weeks prior to the annual meeting of the Society of Exploration Geophysicists.

ARTICLE VII

MEETING

1. The Annual Meeting shall be held in May of each year, and shall be held on the second Thursday of May, unless otherwise specified by the Executive Committee and due notice given to the membership.

2. The Regular meetings of the Society shall be held on the second Thursday of each month except during the months of June, July, and August, unless otherwise provided by the Executive Committee.

3. Special meetings may be called at any time by the President of the Society.

4. The time and place of regular meetings, the nature of the technical program and the entertainment, shall be determined by the Executive Committee.

ARTICLE VIII
AMENDMENTS

1. This constitution may be amended by a three-fourths vote of the members present at any regular meeting, provided that the proposed amendment has been approved for submittal by the Executive Committee and has been moved at a regular meeting previous to the meeting at which the ballot shall be taken.
2. By-laws may be changed by majority vote of members present at any regular monthly meeting.
3. Nothing in this Constitution or By-laws shall be inconsistent with the Constitution and By-laws of the Society of Exploration Geophysicists.

BY-LAWS

I. The Officers and the Executive Committee may arrange for the affiliation with other duly organized groups or societies which by object, aims, constitution or practice are aiding, assisting, or developing the profession of geophysics or allied technology.

II. Until such time as a sufficient number of qualified past Presidents has been created, so as to provide those members necessary to serve on the Executive Committee as provided in the constitution, these Executive Committee members shall be chosen by the Society by a majority vote from open nominations at the Annual Meeting.

III. Prior to the Annual meeting the Treasurer shall close his accounts and submit them to a Committee of three members of the Executive Committee designated by the President. These members shall audit the accounts and then certify their correctness by signing an entry in the cash book.

The new Treasurer shall accept the Society Funds by signing an entry to that effect in the cash book.

IV. The Society shall publish a journal. The journal shall be published at intervals designated by the Executive Committee. All reports to the Society by its officers and committees may be published in the journal. Each issue shall contain a membership list. Each issue shall list all committees. Original papers, reviews, abstracts, notes or information deemed by the Editor to be of interest to the members of the Society shall be published in the journal. The editor shall be sole judge of whether such material is to be published. The executive committee may authorize the printing of the journal and may authorize financing and distribution of the journal.

V. The first editor may be elected at a regular session of the Society following passage of this by-law at a regular meeting.

RULES FOR THE ADMITTANCE OF NEW MEMBERS

1. Any member interested in the Geophysical profession shall be eligible for membership in the Geophysical Society of Tulsa.
2. Applications for membership shall be submitted in writing, and shall be signed by three sponsors who are members of the Society.
3. Applications shall be approved for membership by the Executive Committee.

BRUSH
ELECTRONICS
TEXAS DIVISION

THE BRUSH MAGNETIC RECORDING SYSTEM

Model TR-2 Magnetic Recorder-Monitor

THE BRUSH TWENTY-FOUR CHANNEL RECORDER, FOR TRUCK OR BOAT MOUNTING, CONSISTS OF:

MODEL TR-2 MAGNETIC RECORDER-MONITOR

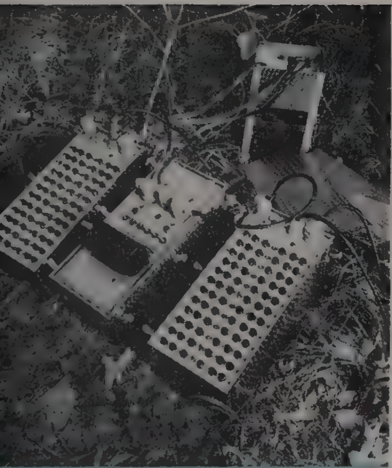
- Twenty-eight channel tape-on-drum recorder.
- Galvanometer style viewing monitor system — for monitoring before and during shooting.
- Direct writing permanent record monitor system, with built-in seismic filters.
- 100 cps timing signal channel.
- Noise cancellation channel (optional use).
- Two information channels (up-hole, time break).
- Twenty-four signal channels.
- Speed lock system for high positional stability.
- New rigid belt drive system for tight, smooth tape movement.

Brush offers a choice of two Amplifier Modulator systems: The Model AM-2 combination Amplifier-Modulators and the Model 721 Seismic Amplifiers with separate Modulator Units. Also, the Recorder and Modulators can be used with any good broad band seismic amplifiers which you may now have available.

MODEL AM-2 AMPLIFIER—MODULATOR UNITS AND CONTROL PANEL

- Twenty-four channels of combined broad band seismic amplifier and frequency modulator.
- Variable soft filtering, for eliminating excessive ground roll or high frequency disturbance.
- Standard high quality seismic amplifier gain, AGC, suppression, line balance, and test features.
- Standard high quality seismic amplifier control panel with trip, suppression control, by-passed first breaks, and test features.

MODEL 521 DUAL PURPOSE SEISMOGRAPH SYSTEM



SUMMARY SPECIFICATIONS

The Model 521 Dual Purpose Seismograph System, consisting of one or two banks of twelve amplifier channels with one control panel each, and of one recording oscillograph, was designed for all types of geophysical operations. Emphasis was placed on ruggedness, long life with minimum maintenance, compactness, and portability. No individual package weighs more than fifty pounds. These units can be used in a light weight recording cab, on truck or boat, and then quickly dismounted for carrying by man.

In addition to the above, main features of the amplifier bank of twelve channels and one control panel are:

1. Fifty pounds weight.
2. 18½" height x 8½" width x 8" depth.
3. Power requirements—16 amps at 6 volts, 27 ma at 90 volts.
4. Input panel, test oscillator, and meter as part of unit.
5. Three selections of mixing.
6. Delay of mixing until after first breaks.
7. Trip on first, sixth, or twelfth trace.
8. Suppression decay.
9. AGC speed of 0.1 second or less, if desired.
10. Non-corrosive, completely water-tight, stainless steel case.
11. Unitized plug-in design to facilitate easy service or replacement.

Main features of the recording oscillograph (six inch, 25 trace recommended for highest degree of portability) are:

1. Thirty pounds weight.
2. 18½" height x 8½" width x 8" depth.
3. Power requirements—Standby— 7 amps at 6 volts.
Operation—18 amps at 6 volts, 15 ma at 90 volts.
4. Clear visibility of galvanometer spots in daylight.
5. Two hundred feet paper capacity.
6. Record length control.
7. Governor controlled paper speed variable from ten inches to sixteen inches per second.
8. Built-in communication system with two stage amplifier.
9. 100 cps note on 25th trace for hunting check.
10. Non-corrosive, completely water-tight, stainless steel case.

The Recording Oscillographs are available in models handling six-inch to ten-inch paper widths and with six to fifty traces.

MODEL 241
SEISMOMETER BASIC UNIT

METER BASIC UNI

The MODEL 241 SEISMOMETER BASIC UNIT is the High Output Basic Unit use in all models of Brush seismometers.

The standard frequencies are 15, 20 and 30 cps. Others may be supplied o special order. The frequency accuracy is held to within one cycle per second.

The matched load voltage sensitivity of a 300 ohm coil is 0.41 volts/inch/se The power output of any resistance coil into a matched load is 5.6×10^{-4} wat per $(\text{inch/sec.})^2$.

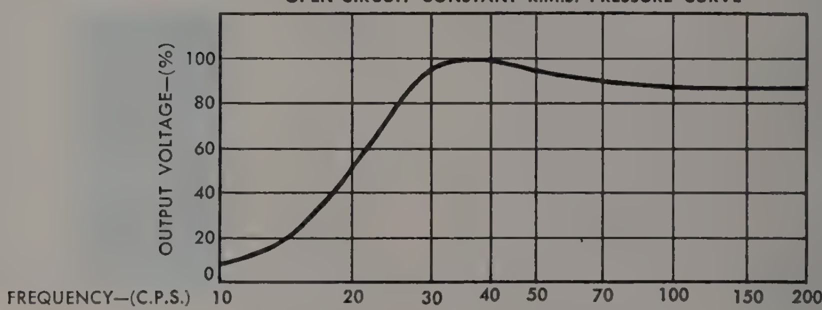
The seismometer is housed in a case machined from solid brass bar stock. Th leads are brought out through glass bead hermetic seals.

MODEL 321-MT PRESSURE DETECTOR

2½" x 6" • 3 lbs. in Air • 2¼ lbs. in Water

Operating Principle ...... Piezoelectric ceramic with matching transformer.
Ruggedness .... Will survive at least 20 7-ft. drops to concrete floor and at least 200 lb./in.^{2} pressure.
Sensitivity .... 0.4 volts/atmosphere—0.4 microvolts/dyne/cm^2.
Frequency .... Natural resonance of 22 cps.
Damping .... No load —50% critical.
300 ohm load—70% critical.
Impedance .... 300 ohms output impedance at 30 cps.
Recommended Depth of Water .... Without Preamplifier —25 feet or more.
With Model 700 Preamplifier— 2 feet or more.

OPEN-CIRCUIT CONSTANT R.M.S. PRESSURE CURVE



MODEL 700 SERIES PREAMPLIFIE

12 Channel	24 Channel
18½" x 8½" x 5"	18½" x 8½" x 8"
22 Pounds	32 Pounds

Voltage Amplification . . 35.
Power Amplification . . . . 2,000.
Filtering .... Approx. 6 db/octave cut beyond 30 cps to offs normal high frequency emphasis of seismic signa in shallow water.
Input Impedance .... Designed to accept one or more Model 321-M 300 ohm pressure detectors.
Output Impedance ..... 180 ohms with level control at maximum.
Noise (Electrical) .... The noise developed with a 300 ohm resisti input (in a band width whose 50% points a 21 cps and 45 cps with a 24 db/octave low c slope and a 12 db/octave high cut slope) is le than 0.04 microvolt r.m.s. referred to the inpu This is approximately 12 db above thermal nois
Sensitivity .... Of Model 321-MT 300 ohm Detector and Mod 700 Preamplifier is approximately 14 microvolt dyne/cm^2.

MAGNETIC RECORD ANALYZER

BRUSH ELECTRONICS
TEXAS DIVISION

MODEL MRA-1 MAGNETIC RECORD ANALYZER —
for fixed correction, compositing and reproducing.

THE BRUSH MAGNETIC RECORD ANALYZER for central laboratory or field office use provides, for its end product, the visual photographic record of one or many field tapes — with these flexible features:

CORRECTING • COMPOSITING • FILTERING • MIXING

The **MODEL MRA-1** inserts the constant weathering and elevation corrections. It provides time section photographic records with these constant corrections. It composites any number of tapes shot with the same spread and same shot hole (different depths). A broad selection of filtering and two types of mixing are available.

The **MODEL MRA-2** inserts the variable stepout corrections as well as the constant corrections. It provides either time section or depth section photographic records with all corrections inserted. It composites any number of tapes shot with the same spread and different shot hole locations and depths. A broad selection of filtering and two types of mixing are available.

EMONSTRATION UNIT — Now on tour

Contains Magnetic Recording as well as conventional equipment.

Please inquire as to date on which Demonstration Unit will be in your area.

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Formerly Technical Instrument Co.
Division of Clevite Corporation

GEOPHYICAL SOCIETY OF TULSA

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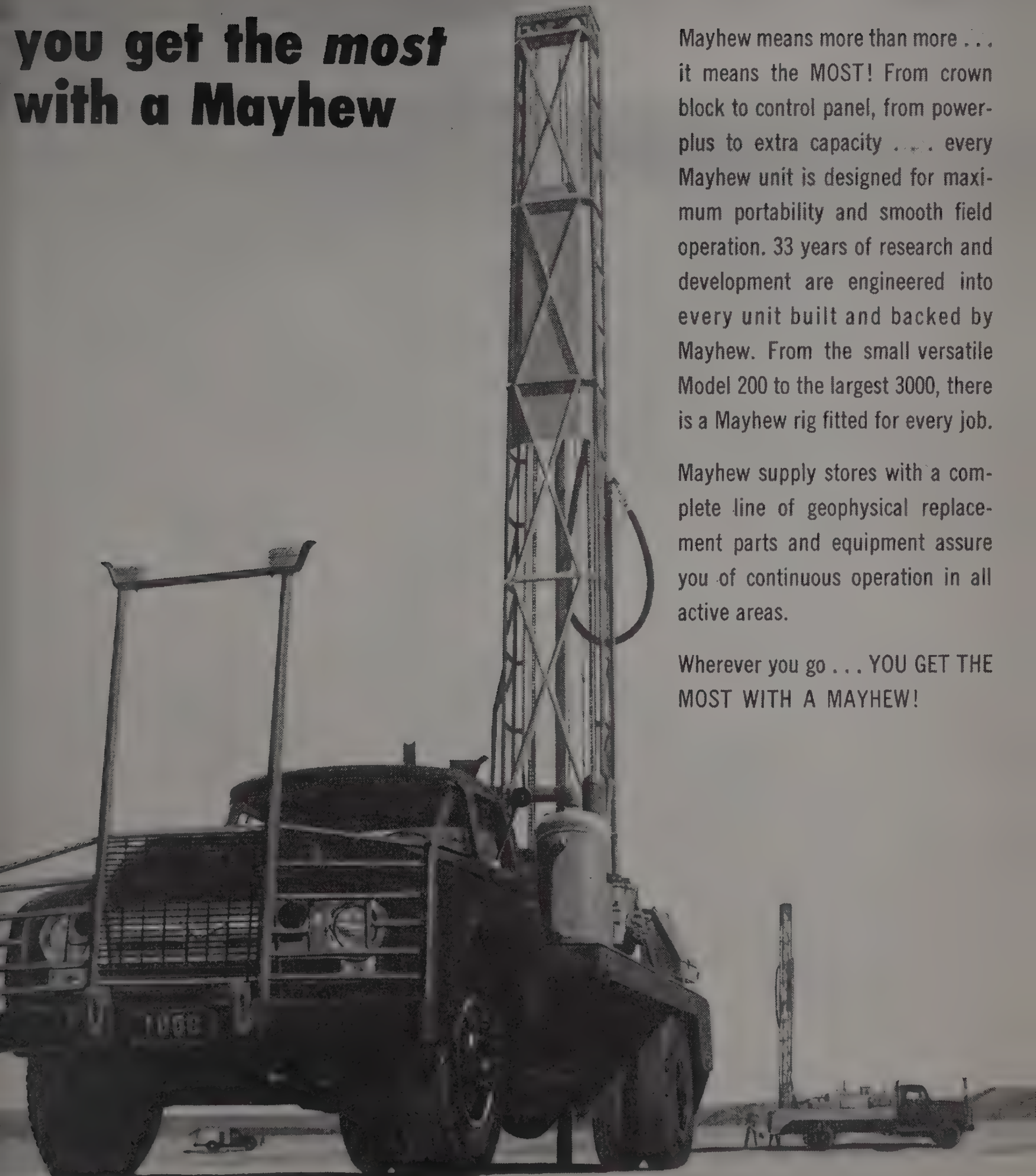

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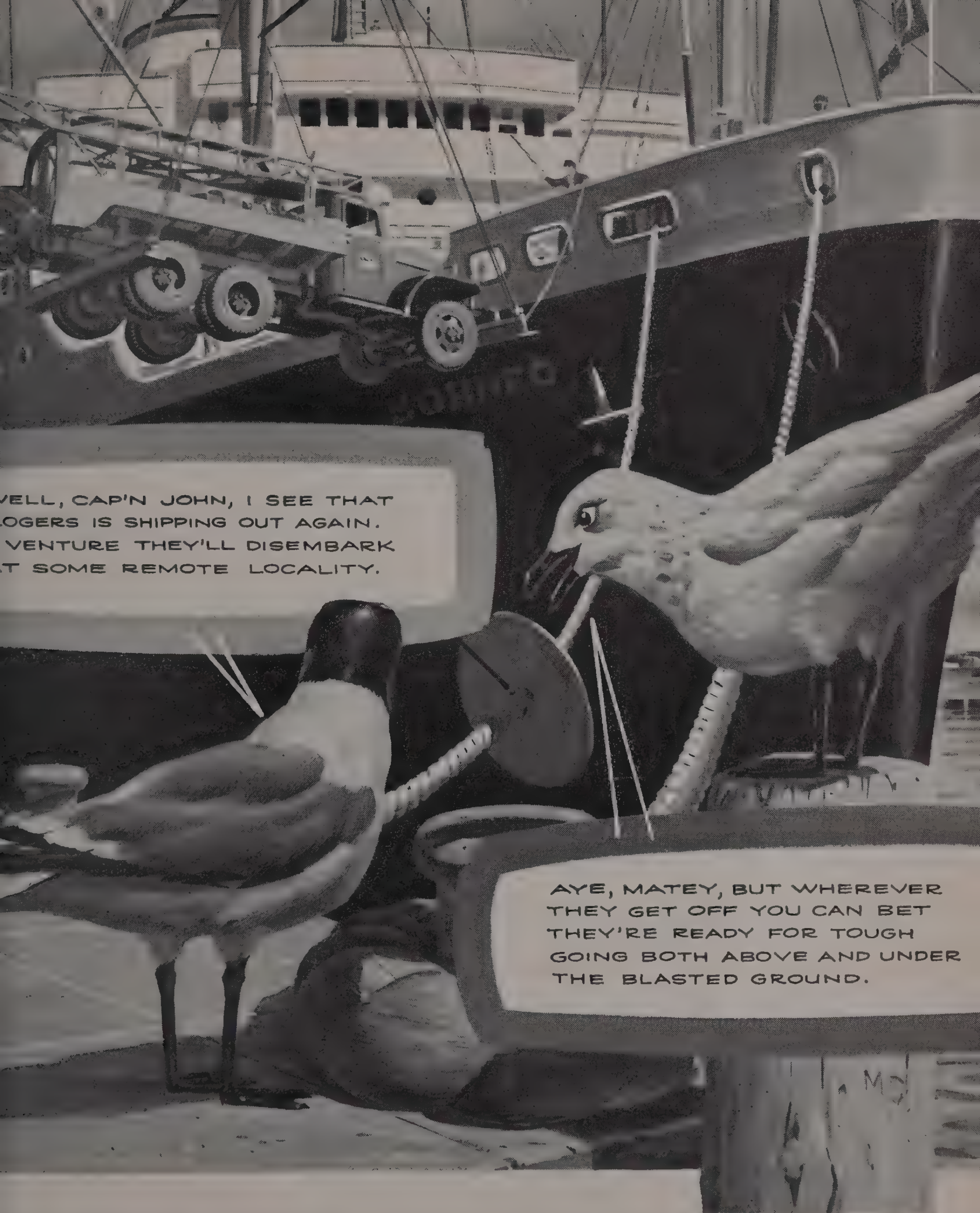
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